Pediatric Endourology Techniques

Prasad P. Godbole
Martin A. Koyle
Duncan T. Wilcox
Editors

Second Edition

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Foreword to the First Edition

I am honored to provide a foreword to this important text. A decade or two ago, a textbook with this title would have contained a chapter about cystourethroscopy, perhaps one about stone management and another about diagnostic laparoscopy for the undescended testis. Scanning the contents for this textbook gives the reader some idea of the creativity and courage of the editor and authors, all of whom have been pioneers in the adaptation of minimally invasive techniques in children. The chapters are arranged by system, making this a valuable and easily navigated reference work. In addition, the format of the chapters is uniform, and the detail allows adaptation of these techniques by anyone with the requisite skill.

The audience for a book like this should extend well beyond those with interest and experience in minimally invasive surgical techniques. At this stage in the evolution of pediatric urology, all practitioners should have an understanding of the full range of surgical options available to the children we serve. Once a curiosity or novelty, minimally invasive surgery has proven to be the gold standard for nephrectomy, management of nonpalpable testes, and management of renal and ureteral calculi. Many of the other techniques outlined in this text are likely to become standard approaches as time goes by. This impressive group of international authors, along with many others, will continue to define the forefront of pediatric urological surgery. I applaud their efforts and look forward to the new techniques that will be revealed in future editions of this book.

Pittsburgh, PA, USA — Steven G. Docimo

Preface

I am pleased to present the second edition of the "Pediatric Endourology Techniques" handbook and video series. Since the first edition was published in 2006, there have been further advances and refinements in endourological techniques. These range from techniques in accessing the appropriate region to technological advances in instrumentation. Since the first edition, most centers have now gained access to basic instrumentation and facilities to perform the majority of procedures safely with good outcomes.

Based on feedback received from the first edition, several new chapters have been added and include areas of physiology, learning curves, and ergonomics of laparoscopy. A number of new internationally renowned authors have contributed their experience to the second edition.

Details of individual pediatric urological conditions are not covered as there are several excellent texts on the subject. All the techniques demonstrated in the accompanying video are from the individual contributor's practice. Many chapters have also incorporated some "tips and tricks" to allow safe completion of the procedures with good outcomes.

This unique textbook and video series will be useful not only to pediatric urologists but also to pediatric surgeons, general surgeons, adult urologists, i.e., any surgeon or surgeon in training who has an interest in minimally invasive surgery.

I am indebted to my coeditors Professors Koyle and Wilcox for their help and support in editing this unique textbook and video series. I am also grateful to the outstanding panel of international contributors for their efforts and outstanding work towards the production of this textbook and video as well as keeping to a tight schedule. I would also like to thank Melissa Morton at Springer for the opportunity to publish this new edition. Portia Levasseur, Development Editor for Springer, deserves a special thanks for keeping the editors and contributors to a tight schedule and her tireless efforts in achieving deadlines for the book.

And most importantly as always, I would like to thank my wife and children who have sacrificed their time and given their wholehearted support to enable me to complete this worthwhile venture.

Sheffield, UK — Prasad P. Godbole, FRCS, FRCS(Paeds)

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Chapter 1
Laparoscopy in Children: Basic Principles

Sean S. Marven and Prasad P. Godbole

Abstract Minimal access surgery (MAS) in children is advancing, and the use of a video endoscope has entered all the surgical disciplines for children. Refinements of instrumentation have empowered surgeons, so that size and weight are no longer considered contraindications to an MAS approach. The pioneering era has passed, and virtually all procedures that could possibly be performed by an MAS technique in children have been accomplished. Further refinements will make the majority of these procedures the gold standard, but much work remains to be done and the evidence base needs consolidating. This chapter focuses on basic laparoscopic techniques.

Keywords Minimal access surgery • Laparoscopy

Introduction

Laparoscopy and laparoscopic techniques in children with urological problems have evolved over the last two decades, thereby allowing the urologist to offer this as an alternative to open surgery. Performing a safe laparoscopic urological procedure requires adequate training and experience with enough cases being performed to maintain skills. It is also important to be conversant with the basic skills pertaining to access and creation of working space and knowledge of physiological changes

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during laparoscopy to enable a safe and successful procedure. The first two aspects are covered in this chapter and will form the basis for the remaining chapters.

Preparation

In a minimally invasive procedure, the stomach and urinary bladder may need to be emptied following induction of anesthesia, but this is not routine. If the colon is loaded, administration of an enema might be considered preoperatively. Careful attention should be given to the preoperative preparation of the umbilicus, from which the cleaning of debris is important. Routine prophylactic antibiotics are unnecessary to cover the access component but may be indicated for the procedure.

Individual judgment should be applied to instances of preexisting coagulopathy or cardiorespiratory compromise that might be exacerbated by the pneumoperitoneum [1]. Previous extensive intra-abdominal surgery, anterior abdominal wall infection, and an intra-abdominal mass require caution but are not absolute contraindications.

Anesthesia

Nitrous oxide should be avoided as this may exacerbate gaseous intestinal distension.

Positioning

An electronic table that allows for a variety of positions is ideal. If the legs are to be supported, all forms of leg support are potentially hazardous, so a splitting table is preferred. For securing and placing patients in a variety of positions, a vacuum "beanbag" may be useful.

Access

Preinfiltration with long-acting local anesthetic and adrenaline of port sites is recommended. Furthermore, allowing the needle to penetrate the peritoneum or body wall helps to site secondary ports. Newer regional nerve block techniques such as transversus abdominis plane (TAP) block are being used but need further assessment and comparison. Access for instrumentation and telescope is usually via ports.

A port in its simplest form consists of a hollow tube or cannula with a cap that contains a valve to prevent gas leak but allows instruments to pass through. The solid trocar or obturator is often sharp but may be blunt. The primary port may be inserted either by a blind puncture after establishing a pneumoperitoneum with a Veress needle or by open insertion using a minimal cutdown technique. Either is acceptable but certain principles must be adhered to (see later).

Ports for children should be of the radially dilating or tissue-separating type; the use of bladed or sharp trocars should no longer be necessary. Cutting trocars are problematic even if shielded and are associated with greater incidence of visceral injury, port site herniation, and bleeding. Increasingly secondary access by stab incisions may be successful and can avoid many of the intraprocedural problems associated with ports, such as dislodgement, gas leak, or limitation of instrument movement [2]. Single port access has become an alternative to multiple ports with similar clinical outcomes but potentially better cosmesis.

Approach

Approaches to the genitourinary tract using rigid telescopes and a video camera include the endoluminal or laparoscopic routes via either the transperitoneal or retroperitoneal approach; the choice depends on the procedure involved and the experience of the surgeon. The retroperitoneal approach is advantageous in avoiding ileus or injury to intra-abdominal viscera, but skill is required to master the technique. Occasionally, approaches may be combined; this allows two images to be seen. Currently, most pediatric urologists with experience in laparoscopy would prefer a retroperitoneal approach, in which the patient may be in the prone, the lateral, or the supine position. Both the transperitoneal and retroperitoneal approaches are described below [3].

Transperitoneal Approach

Primary Port Insertion

Primary port insertion is done by one of two methods: the open or Hasson technique and the closed or Veress technique. Modifications of these techniques include a hybrid technique of limited open dissection with the use of the Veress needle. A newer method of direct visualization is now available using a disposable optical trocar and standard scope that is 5 or 10 mm in diameter or even a finer scope down an optical Veress needle. These may be most appropriate in the obese patient, but little experience of this method has been reported in children. Visual ports and smaller scopes via a modified Veress needles are also available, but again experience with children is limited [4].

No method has been shown to be superior, and each has its own proponents. The open insertion of the appropriately sized primary port by open placement is done under direct visualization of the fascia and peritoneum. Because the umbilicus is a natural scar and the approximate center of the abdomen, it is the usual site of the primary port for intraperitoneal procedures. Once the primary port is placed, the position should be checked with the scope before insufflation begins.

The least invasive method of open primary port insertion is the transumbilical method. In most children with a shallow umbilicus, this approach is quick, involves minimal dissection, and can easily be enlarged to accept 15 mm diameter ports without any obvious scar. Two pairs of hemostats are placed directly on the umbilical cicatrix to lift the abdominal wall gently. A no. 11 blade is used in a perpendicular plane in the longitudinal direction to create a vertical slit in the cicatrix and to enter the peritoneum. This can be confirmed by gently inserting a closed hemostat or blunt scissors.

For children with more than the average amount of subcutaneous fat or a deep umbilicus, the infraumbilical method is favored. A curved incision is made in the inferior umbilical fold and dissection carried down to the midline fascia. The linea alba is incised longitudinally at its junction with the umbilical tube. The underlying peritoneum may be cut with scissors or pierced with a hemostat. In the largest children, a pair of Littlewoods forceps is used to grasp the fascia before incising the fascia. Fascial stay sutures are sometimes placed to prevent outward displacement of the port. If used, these sutures can be secured to a Hasson port or around the tap of a simple port for insufflation. Sutures are usually unnecessary if with careful judgment the aperture is made just small enough to accept the port but still able to grip it, whether using the trans- or infraumbilical method. Inward displacement can be prevented by applying adhesive wound closure strips over the suture and around the port. Alternatively, a rubber catheter cut in small lengths can be pushed over the port; the rubber catheter is then sutured to the skin. A disposable port with an inflatable balloon and moveable cuff is an advanced way of securing the primary port, particularly if the port is to be removed and replaced during a procedure, such as when a large amount of tissue either free or within a bag needs to be retrieved. The inflated balloon prevents outward displacement, while a locking cuff prevents inward displacement, but the port diameter is greater than 10 mm. A port that has a blunt obturator or trocar tip is safest and may come as a bull-nosed or pencil-point type.

The closed method of primary port insertion depends on a Veress needle that is placed through a small incision of the infraumbilical fold just into the fascia with a no. 11 blade. A disposable needle is recommended. The Veress needle is held by the thumb and forefinger down the shaft, like a dart, to allow it to just penetrate the peritoneal cavity. The entry may be associated with a double click. Its position is then ensured by the following tests:

1. The needle movement test
2. Irrigation test
3. Aspiration test
4. Hanging drop test
5. Insufflation of gas or quadromanometric test

(a) Preset insufflation pressure
(b) Actual pressure
(c) Gas flow rate
(d) Total gas used

The pneumoperitoneum is established to a preset pressure for the procedure to the following suggested range:

Newborn infants: <1 year of age, 6–8 mmHg
Children: 1–12 years of age, 8–10 mmHg
Adolescents: 12–15 years of age, mmHg

The primary port is then inserted blind either through the same but enlarged incision or at another site. The only port that should really be used for such entry is a dilating type with Veress needle as the trocar; all other types of trocar are hazardous in the majority of children.

Once the primary port is placed, the position should be checked with the scope and continuation of the insufflation.

Insufflator systems are now available to provide humidified and warmed CO_2 with the possible benefits of reduced tissue desiccation, pain, and cooling. In addition, continuous CO_2 insufflators that recirculate the gas allow the maintenance of the pneumoperitoneum during suction and gas leak but also allow smoke and particle evacuation, are available, and represent the most modern solution.

Single ports are now manufactured with a range of sizes and allow for insufflation and smoke evacuation and are feasible for a range of procedures. These can be used with an incision as small as 2 cm and can be enlarged to 5 cm or more. While there may be some benefits for individual procedures, overwhelming benefits over and above conventional laparoscopy have not yet been fully determined. Reduced port approaches using fewer ports and/or narrower instruments are emerging at the same time.

Secondary Port Insertion

Secondary ports are carefully planned based on the proposed procedure and performed under direct visualization using the telescope. Manual elevation of the abdominal wall during trocar insertion facilitates placement and minimizes the risk of injury to the intra-abdominal organs. Raising the intra-abdominal pressure to as high as 30 mmHg transiently while siting secondary ports may improve safety.

Dilating ports based on a Veress needle are probably safest, and, certainly, those with a sharp cutting, if retractable blade (shielded trocars), should be used with extreme caution. Other “dilating” port trocars are based on a sharp or blunt conical shape or a pyramidal cutting point with dilating shoulders, but neither of these types offers the reliable protection of a Veress needle. The pediatric peritoneum is very elastic and penetrating the peritoneum with a less than sharp or blunt trocar is sometimes problematic and even hazardous.

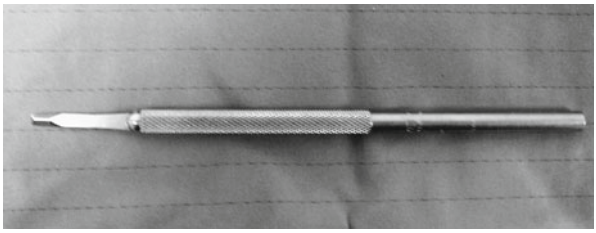

Fig. 1.1 Beaver handle with a no. 69 blade

For many procedures, however, secondary ports may be unnecessary, and access can be gained by carefully creating stab wounds with a scalpel blade. Many surgeons use a no. 11 blade, but this can cut wider than necessary and may therefore cause bleeding or gas leak. A no. 69 blade (Swann-Morton, Sheffield, UK) on a Beaver handle (Fig. 1.1) can be used to create a port hole for 2 or 3 mm instruments, or by inserting the blade further, it can be stretched gently to a 5 mm access hole without the need for a port. When the instrument is removed, gas leaks slowly. But then, as the abdominal wall begins to collapse, the layers of fascia and peritoneum begin to overlap to create a shutter valve that prevents complete deflation. This helpful phenomenon can be enhanced by placing a finger over the incision. This allows the pressure to rise, which then opens up the wound again. The light can be observed through the wound, and the instrument resited in the correct direction. Reducing the number of ports used helps to limit the invasion (e.g., single port nephrectomy).

Retroperitoneal Approach

This approach may be performed with the patient in either a prone, lateral, or even supine position. The approach with the patient in the prone position is described here, as it is the preferred method of the authors.

Anesthesia

General anesthesia should be used via endotracheal intubation; the muscles should be relaxed.

Patient Position

The patient is placed in a prone position. A bolster/sandbag is placed under the pelvis and lower chest so that the renal angle is opened out. This space is bordered inferiorly by the iliac crest, medially by the lateral border of the sacrospinalis, and

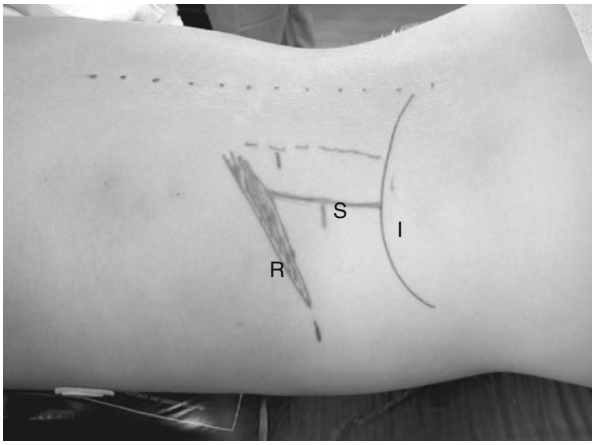

Fig. 1.2 Landmarks and boundaries of the renal space: ribs (*R*), sacrospinalis (*S*), and iliac crest (*I*)

superiorly by the 11th and 12th ribs (Fig. 1.2). Too much elevation will result in approximation of the ribs and the iliac crest, thereby reducing the working space. A useful way of ascertaining adequate support and elevation is by passing a hand below the elevated trunk. Easy passage of the upturned palm indicates adequate positioning. The renal angle may be further opened out by slightly abducting the entire pelvis away from the affected side. Finally the patient should be positioned as shown in Fig. 1.2 at the very edge of the table on the affected side to allow easy maneuverability of the instruments. The arms and legs should be well supported and padded (Fig. 1.3).

Access

The primary port is inserted at the lateral border of the sacrospinalis midway between the iliac crest and the 12th rib. A 5 mm/10 mm incision, depending on the size of port, is made in the skin. A blunt artery forceps, such as a Dunhill forceps, is "walked" off the lateral border of the sacrospinalis through the dorsolumbar fascia until the perinephric area is reached. This is evidenced by a sudden give through the muscle and free movement of the forceps. A ready-made balloon device or the middle finger of an 8.5 glove tied to a 12Fr Nelaton catheter with a three-way tap and 50 ml Luer-Lok syringe is inserted into the perinephric space (the authors' preference) (Fig. 1.4). The balloon is blown up gradually to approximately 200 ml. Too rapid inflation may result in rupture of the balloon. Alternatively, the port may be inserted and the space created using the telescope itself. Once the balloon is deflated, the balloon is removed and the port inserted. The working ports are placed just inferior to the tip of the 11th rib, and, if required, a second working port is placed under vision through the sacrospinalis muscle either in line with or superior to the primary port. The insufflation pressure is maintained at 10–12 mmHg at a flow rate of 1 l/min [5].

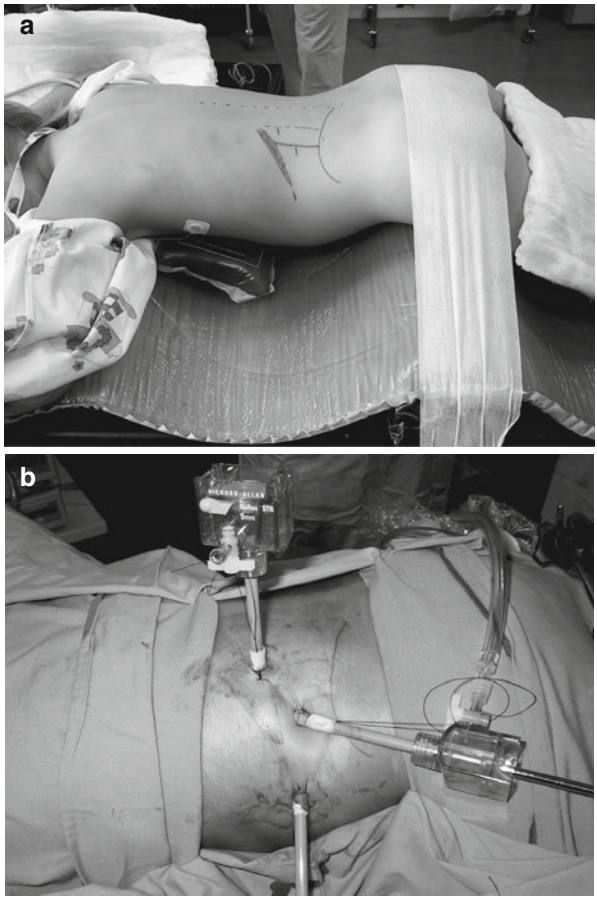

Fig. 1.3 (**a**) Patient position for prone retroperitoneoscopic nephrectomy and (**b**) the ports in situ

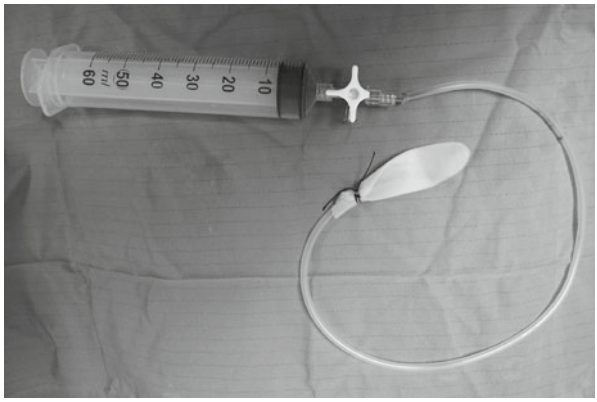

Fig. 1.4 Inexpensive balloon dissector made with the middle finger of an 8.5 glove tied to a 12 Fr Nelaton catheter, a three-way tap, and a 50 ml Luer-Lok syringe

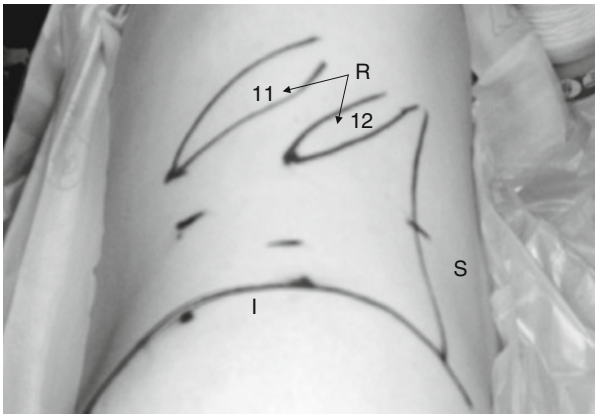

Fig. 1.5 The patient in the right lateral position for a left nephrectomy. The sacrospinalis (*S*), iliac crest (*I*), and ribs (*R*) are shown, as are the port sites

In the case of a lateral approach, the landmarks remain the same but the port position changes (Fig. 1.5). The primary port is inserted in a similar fashion to insertion in the prone approach.

Once the primary and working ports are inserted, the camera may be transferred to the port just above the iliac crest to get good triangulation.

Visualization

Visualization in MAS depends on the creation and maintenance of a working space within an existing or potential body cavity, for example, creating a pneumoperitoneum in laparoscopy or a retroperitoneal space in retroperitoneoscopy. Abdominal wall lifting has not found a place in pediatric MAS. Therefore, the potential retroperitoneal space is expanded initially with balloon devices and insufflation or pneumodissection performed in combination with a blunt or sharp instrument dissection. This will create an acceptable, if smaller, working space compared to the pneumoperitoneum. The initial maximum pressure limits chosen for the intraperitoneal insufflation can vary with the size of the child, but in essence the pressure should be limited to that required to achieve sufficient working space. Preparing a pneumovesicum for ureteric reimplantation will be discussed in another chapter.

Retracting adjacent organs within the working space may be desirable. If so, this is achieved by using retractor systems. Fan retractors are usually large and likely to cause injury. The most useful retractors are of the snake type, as they are flexible enough to allow insertion and then screwed tightly into a preconfigured shape. They may be used in association with a scope/instrument holding clamp that is adjustable or flexible. Suspension sutures and devices are increasingly used to percutaneously suspend any organ or tissue without need for a port. Magnetic systems are also on the horizon.

Instrumentation

In general, disposable equipment is not widely used in pediatric surgery. Note that 5 mm instruments may be useful but the length and the precision are not always ideal for the smallest patients. Disposable instruments smaller than 5 mm have not yet been developed. Instruments that are 3 and 2 mm are becoming more popular, but the shaft's loss of rigidity becomes a problem. But this can be enhanced by using longer ports to stiffen the shaft. Disposable attachments for energy sources make sense, but reusable instruments are generally the best given current developments. The ideal instrument would grasp, dissect, and seal vessels and cut tissue while offering an ergonomically comfortable grip and a wide range of movements or degree of freedom. Because such an instrument does not exist, the selection of instruments is often a matter of personal choice. Vessel sealing technology is technically possible at 3 mm size, but the market forces are holding back this development. Robotic assistance may offer advantages with complex suturing procedures, but this remains largely experimental.

Five mm scopes may be suitable for neonates to adolescents, but a 10 mm scope might be helpful when visualization is difficult because of bleeding. Smaller scopes that are 2 and 3 mm in diameter are rarely advantageous because of the consequent reduction in light. Angled telescopes of 30° or 45° are ideal, as they have a distinct advantage over 0° scopes. They help create a view that looks down onto the tips of instruments rather than along the shaft, avoiding tunnel vision. With practice, any disorientation from angled telescopes should diminish.

Tissue Retrieval

Specimen retrieval in pediatric cases is occasionally complicated by the small size of the trocars employed. A 10–12 mm port will, however, accommodate most specimens. Removal of the port to retrieve tissue may be necessary. The use of a smaller laparoscope at a secondary site while the tissue is withdrawn from the largest port is a useful trick. Simply extending the port wound to the appropriate size is a reasonable maneuver, but the use of a retrieval bag might make this unnecessary. Mechanical tissue morcellators are seldom used, although piecemeal removal from within a retrieval bag may be employed.

Wound Closure

Port site herniation can occur in even the smallest incisions, and therefore attention should be directed to closing the fascial wound with a suture if at all possible. The umbilical site fascia and the fascia of all trocar sites are closed with absorbable sutures. A 5/8 curved, round-bodied needle or a J-shaped needle on 3/0 or 2/0

sutures suffices for children of all sizes. Skin closure is usually achieved using cyanoacrylate-based glue for speed and simplicity; newer preparations are quicker drying and more flexible and create a covering that acts as a dressing. Approximation of skin edges with a subcuticular absorbable suture is still probably cheaper, but this can be tiresome to achieve. Any dressings are usually superfluous, unless there is persistent oozing, and simply cause discomfort on removal. Port site closure devices are available, but they are not widely used as the primary port can usually be closed under direct vision. Secondary ports of 2–5 mm may not require closure, although in small infants herniation of omentum has occurred in even 3 mm wounds.

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Chapter 2
Ergonomics of Laparoscopy

Chad M. Gridley and Hiep T. Nguyen

Abstract Laparoscopy is a surgical field that has been active for several decades, but many of the harmful, long-term effects of laparoscopy on surgeons are only now being realized. Ergonomics is a field of science applied to work environments with the aim of minimizing risk of injury. In the setting of laparoscopy, ergonomics studies have elucidated some of the current drawbacks of laparoscopy. This chapter evaluates the risk factors, available instruments, and operating room setup for laparoscopic surgery. Additionally, potential solutions and methods of decreasing the risk of injury are examined. By possessing knowledge of the drawbacks of laparoscopy, surgeons may be able to protect themselves and prevent injuries.

Keywords Ergonomics • Laparoscopy • Laparoscopic instrument • Surgeon injury

Laparoscopic surgery is a relatively young field; therefore, some of the long-term effects on surgeons are just starting to be recognized and remain relatively unstudied. The field of study that exists to study negative physical actions in the workplace and find ways to correct them is called ergonomics. Ergonomics is often defined as the "science of fitting the work environment to the worker" [1]. In order to gain knowledge of these effects within the realm of laparoscopic surgery, one must first take note of some differences between laparoscopic surgery and open surgery.

Laparoscopic surgery differs from open surgery in several ways. First, open surgery provides surgeons with a relatively high degree of freedom, allowing the surgeon to work within the natural six degrees of freedom. Laparoscopic surgery,

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conversely, limits the surgeon to only four degrees [2]. Second, during open surgery, work is done in line with the surgeon's visual axis. Yet during laparoscopic surgery, the motor actions of the surgeon is decoupled from the visual axis, often causing a mental disconnect. Finally, the surgeon is provided with a 3-dimensional view as well as direct tactile feedback during open surgery. In contrast, a laparoscopic surgeon loses both tactile feedback and depth perception.

These differences pose significant problems for laparoscopic surgeons and often force surgeons to adopt movements and postures in order to overcome some of the mentioned disadvantages. These actions are not always ergonomically correct and are oftentimes associated with improper body posture, difficult repetitive movements of the upper extremities, and prolonged static head and back postures [1].

In general, the laparoscopic surgeon's posture is an upright position with fewer movements of the back and infrequent weight shifting compared to open surgery. An upright posture consisting of a straight head and back is known to cause strain [3]. Furthermore, because the surgeon's attention is focused on a monitor during laparoscopic surgery, the surgeon adopts a static posture. Infrequent changes in position allow for maintained pressures on the back, which in turn are associated with increasing fatigue over time [3].

Pain is reported by surgeons to be one of the most commonly experienced problems associated with laparoscopic surgery. A survey of 149 surgeons indicated neck pain and arm pain were experienced in 8 and 12 % of surgeons, respectively [4]. Stiffness of the neck and arms was reported by 9 and 18 %, respectively [4]. Another study found that 20 % of laparoscopic surgeons surveyed experienced upper and lower back pain during surgery and an additional 20 % had shoulder pain and numbness [5]. Moreover, the same study found there was a spectrum in the incidence of pain associated with different types of laparoscopic cases. Hand-assisted laparoscopic surgery had the highest association with injury [5]. Robot-assisted laparoscopic surgery had the lowest, and standard laparoscopic surgery fell in the middle [5]. In general, it is suggested that 87 % of laparoscopic surgeons have at some point experienced performance-related symptoms during surgery [6].

Physical strain experienced by surgeons during laparoscopic surgery is real and quite prevalent. In a survey of 260 surgeons, 29 % admitted having had received treatment for physical strain, with half of those requiring physical therapy [7]. Fittingly, of those reporting strain from minimally invasive surgical techniques, only 16 % reported having received ergonomic training [7].

Risk Factors for Surgeon Injury

Several studies have suggested that certain surgeon characteristics are associated with an increased risk of developing morbidity due to performing laparoscopic procedures. Franasiak et al. observed that those at the greatest risk were surgeons of younger age, shorter time in practice, smaller glove size, and shorter stature [7]. It has been reported that laparoscopic surgeons early in their education use 130–138 %

greater force and torque when performing laparoscopic surgery compared to their more experienced counterparts [8]. It is rationalized that as a surgeon gains more experience, hand-eye coordination is increased, as does efficiency in handling endoscopic instruments [8].

Similarly, it has been reported that finger numbness and eyestrain are less common in experienced surgeons. Hemal et al. showed that 13 and 16 % of surgeons with greater than 2 years of experience reported finger numbness and eyestrain, respectively, compared to 31 and 40 % of surgeons with less than 2 years of experience [9]. The authors suggested that surgeons first starting out in their career may not have received proper ergonomic training during their surgical education and that over time, they learned through experience to adjust their technique to decrease symptoms [9].

In contrast, Park et al. report that the single most predictive risk factors for the development of laparoscopic surgery-related symptoms were in those surgeons with the highest laparoscopic case volumes. The surgeon's age or years of laparoscopic experience did not seem to have a significance of an impact [6]. The available evidence, although somewhat conflicting, shows that there are main factors that can be targeted in hopes of decreasing the risk of laparoscopy-induced injuries for surgeons.

Laparoscopic Instruments and Their Ergonomics

Current laparoscopic instruments were adopted from those used in procedures minimally related to their current use. EMG studies demonstrated that the use of laparoscopic instruments can increase muscular work of the forearm and thenar compartment by a factor of 2–5 compared to using a standard hemostat [4]. Further studies indicated that when using laparoscopic instruments, EMG percentages exceeded accepted threshold limits, suggesting that the muscles were working in excess of their ability to avoid fatigue [10]. Nonergonomic instruments can promote many uncomfortable movements and maneuvers. For example, the wrists can be forced into a flexed position with ulnar deviation (Fig. 2.1a, b) [11]. This movement moves the surgeon out of the neutral position and can cause compression of the median nerve.

Nerve compression is a major concern for laparoscopic surgeons. The development of neuropraxia has been commonly attributed to performing laparoscopic procedures. Prolonged pressure of the radial digital nerve of the thumb and the palmar branch of the median nerve is a relatively common cause of digital neuropraxia [12]. In a survey of 50 laparoscopic surgeons, 40 % had experienced neuropraxia with symptoms lasting a median of 9 h and occurring a median of 4.5 different times [13]. There was a direct correlation between the frequency and total number of cases performed annually [13]. It is theorized that in an effort to perform precise movements and reduce tremor, surgeons will maintain an excessively forceful grip of the instrument compressing digital nerves [13].

These major drawbacks of the laparoscopic instruments can be attributed to their present design. Instrument shape poses a major problem for surgeons. The style of the most commonly used laparoscopic instruments possesses a scissor style with a

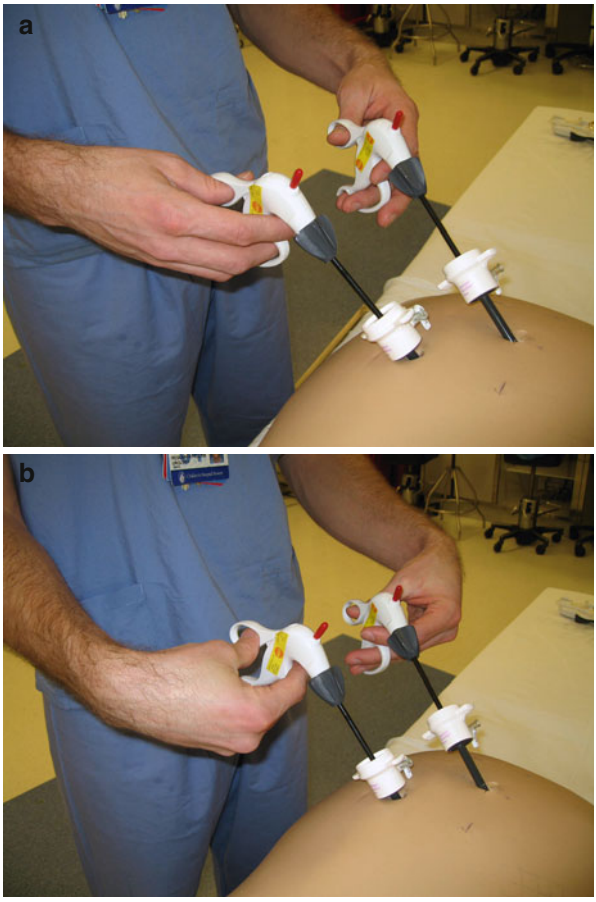

Fig. 2.1 (**a**) Proper wrist angle. (**b**) Improper wrist angle increasing pressure on the carpal tunnel

pistol grip which requires thumb manipulation [14]. Furthermore, in the same study, Van Veelen et al. defined the ergonomic requirements for laparoscopic instruments and noted that the design of that most common style only met three out of the eight ergonomic requirements that they defined [14]. It has been observed that the scissor-handle type of laparoscopic instruments is associated with excessive wrist excursions during high-precision tasks and the cylindrical-handle type is associated with excessive wrist excursions during global tasks [15]. Moreover, laparoscopic instruments often possess narrow contact surfaces that are not ideal for accommodating the surgeons' hands and fingers [11]. This puts pressure on small areas of the fingers that can eventually lead to numbness during the case.

The force required during the use of laparoscopic instruments is another major problem. When using the laparoscopic instrument, force must be applied, extending down the length of the instrument to the tip. This correlates with a force requirement of 4–6 times that of open surgery instruments [2]. This creates a problem for surgeons with busy caseloads as high forces must be maintained consistently during surgery, which

can quickly result in fatigue. Force creation has been found to be a significant problem for surgeons with relatively small hands. Those with a glove size of 6.5 or smaller have been observed to experience significantly more difficulty with the use of laparoscopic instruments [16]. This is troubling as 36 % of the study group had a glove size of 6.5 or less [16]. Glove size ranges from 5.5 to 9 at increments of 0.5, yet there exists only one size of laparoscopic instrument [6]. Surgeons could potentially benefit from having the option of choosing from a collection of differently sized laparoscopic instruments.

In a recent analysis of the available laparoscopic instruments, it was noted that, objectively, no recommendation for a "best" laparoscopic instrument style could be made [17]. All instruments cause wrist and hand fatigue to a certain level because of their nonergonomic handles, which contribute to surgeons developing rapid fatigue, pressure areas, and nerve irritation [17]. Not uncommonly, surgeons tend to have their "favorite" tool type without any apparent consensus [17]. In another study, surgeons were evaluated using a laparoscopic simulator, and it was observed that pistol grip-style instruments tend to result in a poorer operative product compared to in-line grip style [18]. In-line grips resulted in fewer non-goal-related movements and shorter operative time [18]. However, the surgeon's forearm workload was found to be the same when using either style of laparoscopic instruments [18].

Monitor Position and Ergonomics

Several studies investigated the proper placement of the video monitor during laparoscopic cases. Monitor height has the ability to affect the workload placed on the surgeon during the case and can affect performance [19]. Monitors should be placed in front of the operating surgeon between the surgeon's head and elbows to maintain flexion at the neck between 15° and 45° (Fig. 2.2) [20]. One study further suggested placing the monitor directly in front of the surgeon at the level of the hands, returning the surgeon to a posture normally maintained during open surgery [21]. In theory, this setup would allow sensory and motor control to be closely related spatially with the instrument controls [21]. Additionally, the placement of extra monitors is recommended as it helps minimize stress for assisting personnel.

The Fulcrum Effect

When performing laparoscopic surgery, the fixed ports that provide the entrance for the instruments to enter the abdomen create a fulcrum effect (Fig. 2.3). Initially, surgeons may have some difficulty overcoming the backward nature of operating with the instruments due to the fulcrum effect because this phenomenon results in a conflict between the surgeon's visual input and proprioceptive input [22]. Despite the initial difficulty, the brain learns to process the conflicting information with minimal attention required by the surgeon.

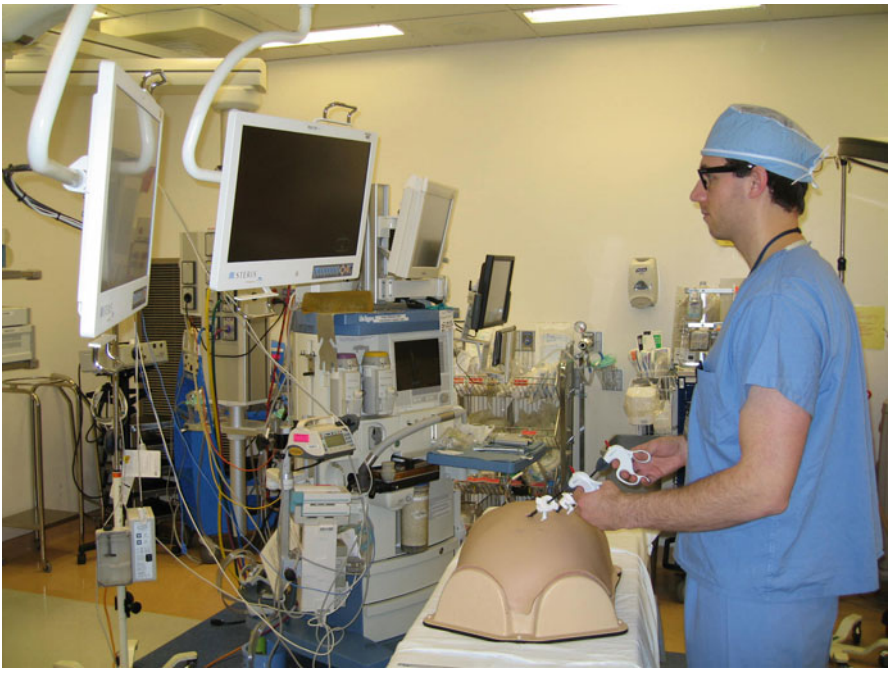

Fig. 2.2 Monitor is placed in front of surgeon, neck flexion between 15° and 45°

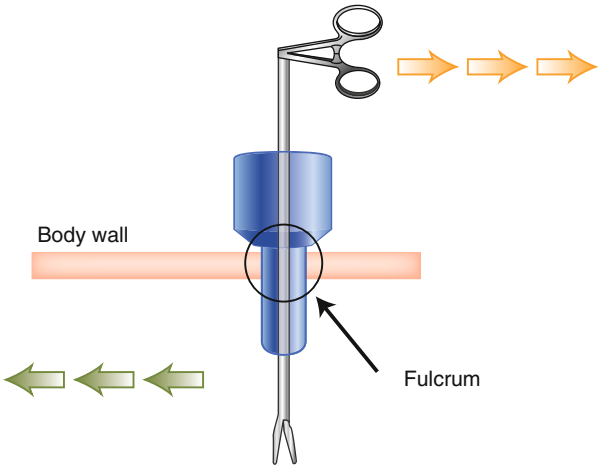

Fig. 2.3 The fixed point of instrument insertion acts as a fulcrum, causing opposing movement of the tip relative to the surgeon's hand

There are aspects of the fulcrum effect that cannot be overcome with practice, though. For example, the fulcrum effect can sometimes limit goal-directed movements of the surgeon. The point of instrument insertion acts as a fixed point, limiting manipulations by the surgeon [23]. There are times when the surgeon simply cannot carry out a task while maintaining ergonomically correct form. Consequently, this leads the surgeon to assume uncomfortable body position and awkward upper extremity movements [2]. Furthermore,

awkward wrist movements are sometimes employed during high-precision tasks, such as suturing, that include extreme wrist supination and ulnar/radial deviations [2].

Potential Solutions

There are potential solutions that may help surgeons to avoid the aforementioned problems associated with performing laparoscopic surgery. Uhrich et al. observed that experienced surgeons performed laparoscopic tasks at a lower total exertion level than that of less experienced surgeons despite continuing to exceed EMG threshold limits [10]. This observation suggests that with continued practice and training, a surgeon develops habits such as learning effect, muscle compensation, and postural shifts that help to minimize overall fatigue [7, 10]. In fact, it has been observed that frequent posture changes were the favored method of minimizing symptoms and discomfort [6]. Another commonly utilized solution is to spread out laparoscopic cases over time or even to decrease the total caseload [7].

Problems commonly associated with long case duration may be overcome with proper laparoscopic surgical form. When the procedure allows, the surgeon should keep his or her elbows relaxed at his sides with the forearms bent to be parallel with the floor (Fig. 2.4) [24]. Ideally, the operating table should be placed within a factor

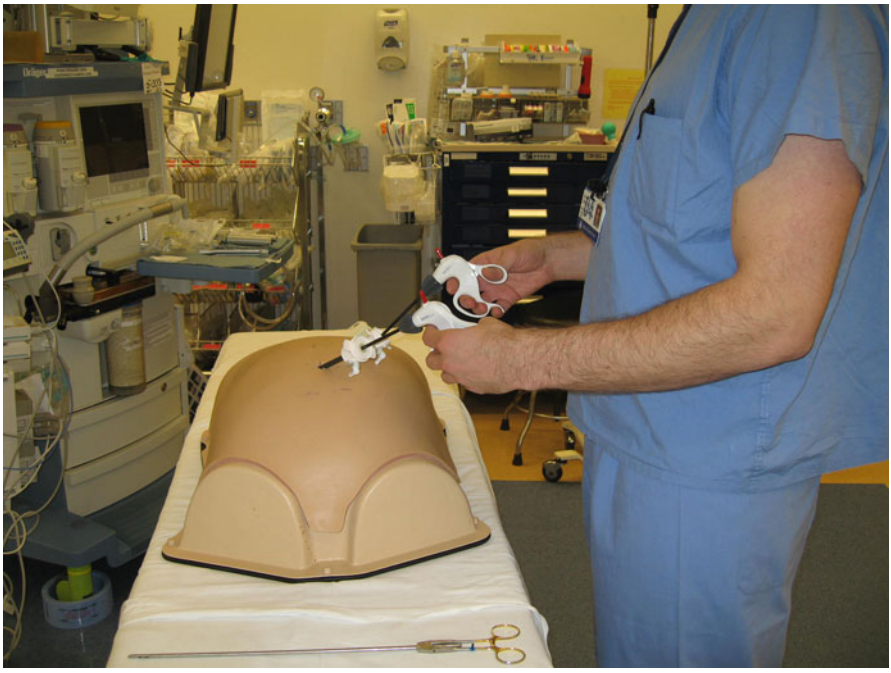

Fig. 2.4 The elbows at side maintaining the forearms in parallel to the floor

of 0.8–0.7 of the operating surgeon's elbows, allowing for the most freedom of movement and a minimization of discomfort in the back, shoulders, and wrists [23]. The suggested height of the operating table roughly correlates the height of the operating surgeon's pubic bone [23]. Once the table has been set for the operating surgeon, all other staff who are directly involved with the surgery (assisting surgeons, scrub nurse, etc.) should utilize step stools to be at proper ergonomic working level. Proper table height will also ensure that the angle at which the laparoscopic instrument enters the patient stays within the ergonomically correct angle of 37° within the horizontal [24].

Finally, devices are currently being created to help reduce strain on the operating surgeon during laparoscopic procedures. As an example, armrests can provide forearm support, improving control of the hands as well as reducing tremor [25]. The use of armrests is associated with reduced fatigue in the upper spine, shoulders, and arms during long procedures [25].

Alternative Minimally Invasive Techniques

The use of a robotic operating system has been shown to be less demanding of the surgeon during procedures. With regard to the thenar muscle group, the robotic system requires less activation and may reduce the incidence of thumb fatigue and neuropraxia [26]. Furthermore, utilization of the robot might be less mentally stressful compared to laparoscopic surgery [26]. Operating with less mental stress would most likely translate to less muscle tension and muscle fatigue. Although robot procedures for simple tasks were shown to take longer relative to the laparoscopic equivalent, complex procedures showed no difference in the surgical time [26]. Utilizing laparoscopic techniques for simple, quick procedures and robotic techniques for more complex, long procedures may be a solution to reducing surgeon's morbidity in performing laparoscopic surgery.

Conclusion

In summary, the ergonomics of laparoscopic surgery is a topic still early in its development. Discomfort during procedures and lingering symptoms following surgery are common problems experienced by many laparoscopic surgeons. There currently appears to be no ideal style for laparoscopic instruments available today, and advances in the development of more ergonomically correct instruments need to continue. Surgeons can take certain steps, though, to minimize the risk of injury during surgery by maintaining proper posture and surgical setup and knowing the limits of laparoscopy.

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Chapter 3
Basic Principles of Robotic Surgery

Anup B. Shah and Mohan S. Gundeti

Abstract The utilization of robotic assistance in pediatric urological surgery offers the potential to improve clinical outcomes and reduce complications through minimally invasive techniques. Nevertheless, there exist few resources on robotic surgery that provide a combined discussion of historical perspectives, technical considerations, and practical implementation strategies in the setting of pediatric urology. In this chapter, we draw on expertise from experienced robotic pediatric urologists to describe principles of robotic surgery in current practice. First, we present a brief historical perspective on robotic surgery in pediatric urology and a stakeholder-based analysis of the growing use of robotic assistance. We then discuss specific considerations with regard to anesthesia, patient positioning, port placement, and instrumentation unique to the pediatric urological population. A practical approach to surgeon training and team building is outlined. Finally, we explore the promise, challenges, and limitations of robotic assistance in pediatric urology.

Keywords Robotic-assisted laparoscopic surgery (RALS) • Pediatric urology • da Vinci Surgical System (DVSS) • Robotics in pediatric urology • Minimally invasive surgery (MIS)

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A Historical Perspective of Robotic Surgery

The modern adoption of robotic-assisted laparoscopic surgery marks a major shift in the history of minimally invasive surgery. The superior stereoscopic visualization, ease of anatomical access, and wrist articulation of instrumentation unique to robotic-assisted laparoscopy have attracted the attention of the surgical community as an improvement over traditional laparoscopy. Adoption of the technology has been rapid in spite of the significant financial cost of robotic technology. In 12 years since the FDA-approved Intuitive Surgical's da Vinci Surgical System (DVSS) in the year 2000, the company notes that over 2,400 robotic devices have been sold and installed in over 1,900 healthcare institutions, with an average cost over $1.7 million per installment [1, 2]. Drivers for adoption include patient and surgeon preference, which will be explored below.

Initially approved for cardiothoracic procedures, robotic technologies have been widely adopted by a number of specialties including adult urology, gynecology, otolaryngology, and general surgery. Adult urologists have adopted robotic technology in both upper and lower urinary tract procedures. Of interest, the National Cancer Institute reports that four of five radical prostatectomies performed in the United States are robotically assisted [2].

Pediatric urologists have adopted robotic-assisted procedures in select centers. Procedures such as pyeloplasty for ureteropelvic junction obstruction, partial and complete nephrectomy, and both intravesical and extravesical ureteral reimplantation for reflux are in practice. Complex procedures have also been reported, such as complete intracorporeal robotic-assisted augmentation ileocystoplasty and Mitrofanoff appendicovesicostomy for neurogenic bladder dysfunction [3].

Stakeholders in Robotic-Assisted Laparoscopy in Pediatric Urology

Patient, surgeon, and healthcare considerations fuel the adoption and availability of robotic-assisted laparoscopy in pediatric urological surgery. For patients and parents, the promise of robotic-assisted surgery lies in the reduced perioperative mortality and improved postsurgical cosmesis. Several studies have noted significant reductions in perioperative hospitalization, reduced incisional pain, and reduced need for opiate pain medication. Improved cosmesis due to "keyhole" incisions (1–2 cm) has also been noted as an important benefit of minimally invasive surgery over large incisions in open surgery. The driver for patient (or parent) preference in the growth of robotic assistance is aptly reflected in the analogous world of adult urology, where the rise of robotic-assisted prostatectomy has been partially attributed to "word-of-mouth" endorsements by recent surgical patients to prospective patients.

Surgeon preference has also contributed to the rise in robotic-assisted technology. In particular, improved anatomical access into the pelvis, high-definition stereoscopic vision, and the ability to articulate instrumentation in 7 degrees of

freedom render robotic technology a very attractive option for minimally invasive surgery. Also, the practical seated position of the surgeon at the control console with immersive visualization is ergonomically favorable for longer operations. Although a learning curve for robotic operation exists, it is generally thought to be shorter than conventional laparoscopy with a much quicker time to mastery [4]. Moreover, robotic-assisted surgery is associated with less blood loss and thus less need for transfusions and potential complications. A surgeon-centric drawback of robotic surgery is the association of longer operative times with robotic assistance; however, operative times are noted to decrease with increasing case volume and experience [5].

Broader healthcare considerations for robotic surgery include clinical outcomes, cost-effectiveness, and access to new healthcare technology. Clinical outcome studies for robotic-assisted surgery versus open surgery have become increasingly important in defining the role of robotic assistance in pediatric urological practice. Few studies have systematically reviewed outcome data that includes head-to-head comparisons between robotic and open procedures, yet the burden of proof for widespread adoption has not been achieved in many commonly performed robotic procedures such as nephrectomies, pyeloplasties, and ureteral reimplantations. In addition, the robotic operations currently in practice by pediatric urologists are generally unstandardized, and thus there is a difficulty in assessing the generalizability of cohort and case–control studies that do include outcome data. Nevertheless, these studies are critical and will continue to define the role of robotic assistance in surgical practice. The cost considerations of robotic surgery in respect to the backdrop of increasing national healthcare expenditure have also been a point of controversy. Due to the high capital cost of $1.5 Million with additional maintenance and per-operation instrumentation costs for the popular DVSS technology, several studies have found a significant increase in operative costs for their respective disciplines and specific surgeries [4]. Nevertheless, limited reports in pediatric urology report equivalence or perhaps cost saving from robotic-assisted surgery primarily due to reductions in hospitalization and pharmacy costs. Surely, a clearer idea of cost effectiveness will continue to shape the adoption and availability of robotic technology in pediatric urology. Lastly, given the high capital costs and relatively rare technical expertise in robotic surgery, a concern of healthcare disparities exists such that rural and suburban healthcare centers will lack the ability to offer minimally invasive surgeries, leaving a large population unable to access potentially improved treatments.

Basic Principles in Robotic-Assisted Laparoscopic Pediatric Urology

Components of the Robot and Surgical Suite Layout

See accompanying video: “Basics of pediatric robotic-assisted laparoscopy” (Video 3.1).

Anesthesia

Anesthesia for robotic-assisted laparoscopy in pediatric urology is characterized by generalized anesthesia with special considerations given to physiological changes associated with pneumoperitoneum and surgical positioning.

Presurgical anesthetic evaluation for the pediatric patient should begin with a thorough physical exam. A careful, systematic examination of the renal, cardiac, neurologic, and respiratory systems should be undertaken, and family history should be elicited prior to surgery with special attention to possible malignant hyperthermia. Presurgical phlebotomy is generally discouraged due to its anxiety-inducing nature and the possibility of compromising intravenous access in the pediatric population [6].

Fasting recommendations are provided by the American Society of Anesthesiologists (ASA) and are less restrictive than the "nothing by mouth after midnight" recommendation, which can result in an unnecessary risk of hypoglycemia and dehydration [7]. During preparation for the operating room, anxiety is managed pharmacologically. Midazolam is typically administered, which has many routes to availability [8].

During operation, the anesthesiologist is mostly concerned with the airway, managing unconsciousness, maintaining fluid status, and hemodynamic stability. General anesthesia is administered and an airway endotracheal tube is placed. Anesthetic agents used for induction are typically inhalation-based, and nitrous oxide may be given to aid induction but is generally avoided due to a potential for gaseous distension of the intestines. Muscle relaxants are administered to facilitate temporary paralysis during surgery, and newer agents help facilitate rapid reversal after surgery. The anesthetist must be vigilant and attentive to changes in body temperature given the documented increase in body temperature reported in robotic surgery, potentially due to the instrumentation or a hypermetabolic response to surgery [9, 10].

The pneumoperitoneum results in physiological changes that must be respected during surgery. Carbon dioxide is a safe, non-embolizing, noncombustible gas that is used to inflate the abdomen at pressures at or below 12 mmHg during operative time; however, this may be variably based on the age of the patient, with lower pressures recommended for younger patients. Carbon dioxide insufflation results in both hypercapnia and superior displacement of the diaphragm, altering respiratory mechanics. These changes necessitate increasing the minute ventilation rate by 25–75 % to maintain proper carbon dioxide levels [11, 12]. Moreover, positioning of the patient for bladder and pelvic surgeries requires a head-down Trendelenburg position, altering cardiac function by decreased venous return, increased afterload, and decreased cardiac output which should be carefully followed intraoperatively. Increased peritoneal pressure also decreases renal blood flow and thus urine output, and due to the possibility of inherent renal dysfunction or urine loss into the peritoneum during surgery, urine output is not a reliable marker for volume status. Moreover, the Trendelenburg position is associated with increased intraocular pressure and has been associated with corneal abrasions in adult patients [13]. To prevent

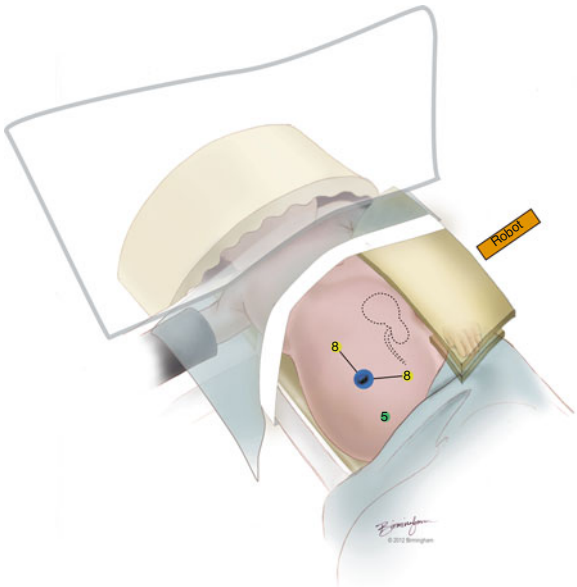

Fig. 3.1 Positioning and port placement for robotic left renal procedures

supraphysiologic intraocular pressures, fluid restriction is recommended during the procedure with repletion postsurgically.

Positioning and Port Placement

Proper positioning of the patient in robotic surgery helps prevent patient injury, improves visualization, and facilitates adequate range of motion for the surgical instrumentation. Two positions are described below from the author's experience, one for the upper urinary tract or renal surgeries and the other for bladder surgeries such as ureteral reimplantation, appendicovesicostomy, or bladder augmentation.

Renal Positioning

Positioning children for renal procedures should begin by placing a Foley catheter into the bladder. Next, the patient should be positioned in a 30–45° lateral decubitus position with the ipsilateral side raised. Slight flexing at the contralateral flank is useful and can be accomplished by padding the flank underneath with a variably sized roll depending on the size of the patient. The ipsilateral arm rests comfortably on the patient's side in the natural anatomical position, whereas the contralateral arm rests outstretched supported by a bedside attachment limb support. The patient should be provided with sufficient foam padding at all pressure points to prevent injury as well as provided with a large foam padding on the head protecting the airway and face in the case of camera approximation during operation. The robot will dock on the patient's ipsilateral side (see Fig. 3.1).

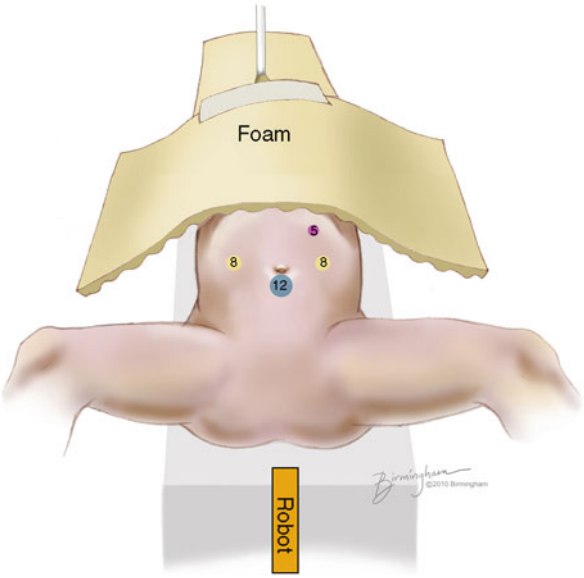

Fig. 3.2 Port placement and positioning for pelvic procedures

Pelvic and Bladder Surgeries

Positioning children for bladder procedures should begin by placing a Foley catheter into the bladder. The patients during bladder procedure are placed at the end of the operating table in a lithotomy position with stirrup supports and a slight Trendelenburg angle. The patient should be provided with sufficient foam padding at all pressure points to prevent injury. The robot will dock from the foot of the table, between the patient's legs. Of importance, the camera swinging during the foot-docked robot position may come near the patient's face, and thus adequate foam padding protecting the face and airway is critical (see Fig. 3.2).

Port Placements

Port placement for all robotic surgeries requires an initial insufflation of the peritoneal cavity and the subsequent placement of working and assistant ports. The preferred approach for initial insufflation in pediatric cases is the open Hasson technique. Initial insufflation is set to 10–15 mmHg of carbon dioxide. Nitrous oxide is not preferred given the potential for intestinal distention and loss of visualization. A trocar is inserted for the 12 mm/8.5 mm camera port via the preferred technique [14].

Two 8 mm instrumentation ports are generally used during operation. Ports are placed after pneumoperitoneum is achieved and under direct vision with a 0° flat or 30° upward-facing lens. The ports are placed midline 6–10 cm superior and inferior to the umbilicus for renal surgeries or laterally 6–10 cm away from midline at

or above the level of the umbilicus. If the patient's umbilicus to pubic symphysis distance is below 10 cm for pelvic procedures, the camera port should be moved to a supraumbilical position. Adequate spacing (6–10 cm) between ports and the camera is critical to prevent collision. Newer models of the DVSS robot (S and Si) tolerate closer spacing between ports. An additional 5 mm assistant port is often useful for needle delivery and can be placed as described in the included diagrams.

After port placement surgery, the pneumoperitoneum pressure should be reduced to 12 mmHg (10 mmHg for infants), and the pressurized carbon dioxide should be connected to the assistant port to prevent fogging. After instrument change, the pressure of the pneumoperitoneum reliably drops. Reinsufflation should proceed to maintain 12 mmHg during operation.

Visualization and Instrumentation

High-definition visualization is a hallmark of modern robotic-assisted laparoscopy. Three sizes of endoscopes are available on the DVSS: 5 mm (discontinued production), 8.5, and 12 mm. The 5 mm scope allows for a 2D monocular view, whereas the 8.5 and 12 mm endoscopes allow for 3D views with binocular vision. Warming the endoscopes prior to insertion into the pneumoperitoneum as well as attaching the carbon dioxide tubing to the assistant port will help limit fogging of the visualization.

Instrumentation on the da Vinci machine allows for a wrist-like 7 degrees of freedom, which is particularly helpful for complex laparoscopic maneuvers such as suturing. In addition, due to motion control algorithms, movements of the instrumentation are tremor-free. Both 5 and 8 mm instruments are available, yet 8 mm is often preferred by the author due to ease of use and geometrical limitations of angulation of the 5 mm instruments. Currently, the 5 mm instruments require an additional 2 cm of intracorporeal working distance over the 8 mm instruments. The increased distance is a limiting factor in the pediatric population and has discouraged the use of 5 mm instrumentation. The 8 mm instruments include a large needle driver, Maryland bipolar forceps, curved and straight scissors, scalpels, bi- and monopolar cautery instruments, ultrasonic energy instruments, and laser cutters. Appropriate miniaturization of the instrumentation is anticipated in future releases and may facilitate operating in tight anatomical spaces.

Training and Team Building

Adequate robotic training and meaningful mentorship is important for the development of skilled robotic surgeons. Currently, no standardized robotic training curriculum in pediatric urology for practicing pediatric urologists is universally accepted. Nevertheless, specialized fellowships, cadaveric laboratory experience,

and one-on-one training with an experienced robotic surgeon provide opportunities for training. At our institution, we have designed a 5-day immersive training minifellowship for pediatric urologists worldwide [14]. The curriculum includes hands-on supervised training in the laboratory, simulation, dry skills, and didactic lectures. For basic robotic skills, virtual training simulation such as the Robotic Surgical Simulator (RoSS) developed by Simulated Surgical Systems LLC has proved popular among practicing robotic surgeons as a training tool [15]. Also, simulators packaged with the SI dual console DVSS have been useful in training regimens. For more specialized training, the use of a mentor and formalized training has been shown in conventional laparoscopy to impact the learning curve as well as maintenance of the skills in future practice [16].

Team building and training is critical for the development of a successful robotic program. The key to developing a team in robotic surgery is to identify a core group of individuals: a surgeon, anesthesiologist, nurse, and bedside assistant during the first 10–20 cases. This group should also dedicate itself to post-case analysis of each step in the robotic procedure and be engaged in developing solutions to nonideal procedures. Extending the core group to continue refining procedures through 50–100 cases would be beneficial [4].

Looking Forward: Promise, Challenges, and Limitations

Many academic pediatric urology centers are actively pursuing expertise and innovation in robotic-assisted laparoscopy. The promise of robotic-assisted surgery is very attractive: improved 3-dimensional visualization, improved ergonomics, shorter hospitalizations, lower incisional pain, improved cosmesis, and the ability to execute complex reconstructive surgery in a minimally invasive fashion. The modified use of the technology can also help provide surgical services to rural and inaccessible populations via telerobotic means. Moreover, the high technology platform can be seen as a precursor to future automation in digitally controlled surgery. For these reasons, a number of institutions have embraced robotic technology.

Nevertheless, the challenges posed to the use of robotic technology in pediatric urology are clear. Most importantly, outcome studies must demonstrate comparable clinical efficacy and complication rates to open surgery to justify routine use in pediatric urological surgery. Indeed, to justify the high cost and resource investments needed to support robotic technology, it is reasonable to expect that robotic-assisted surgeries demonstrate improved clinical efficacy and reduced complication rates in the pediatric population. Technically, solving the challenges of instrumentation miniaturization and meaningful haptic feedback in robotic assistance can dramatically improve the robotic surgical experience. Currently, the lack of haptic feedback is a major drawback for novice surgeons who tend to tear tissue and break sutures when acclimating to robotic assistance. Current research and development into haptic instrumentation is underway. Proper patient selection is also a

consideration of primary importance. Standardization of robotic procedure techniques is a challenge to surgeons internationally. Training and education must be standardized for surgeons intending on practicing robotic surgery.

The most apparent limitation of robotic surgery is a financial one. As described above, implementation of the DVSS requires high capital investment and continued financial support for maintenance and instrumentation. In addition to financial costs, limitations of robotic surgery include the number of trained pediatric urologists, nurses, and anesthesiologists to support the growing field. Clinical and technical limitations surely lie ahead, and the increasing use of robotic assistance will bring forth limitations that pediatric urologists must confront and acknowledge in order to provide the best care for children.

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Chapter 4
Physiology of Minimally Invasive Surgery Versus Open Surgery

Niki Kanaroglou and Walid A. Farhat

Abstract Endoscopic and minimally invasive surgery (MIS) in pediatric urology affords many benefits when compared to open surgery but also introduces unique physiologic considerations. The surgical team must be aware of the physiologic changes associated with these approaches in order to avoid making MIS detrimental. The knowledge presented in this chapter should bring the anesthetist and the MIS surgeon together to uphold the success of these procedures and ultimately improve the care of children in this setting.

Keywords Minimally invasive surgery • Laparoscopy • Pediatric urology • Physiology • Pneumoperitoneum • Anesthesia

Abbreviations

CBF	Cerebral blood flow
CO	Cardiac output
CO_2	Carbon dioxide
$ETCO_2$	End tidal CO_2
GFR	Glomerular filtration rate
HR	Heart rate
IAP	Intra-abdominal pressure

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ICP	Intracranial pressure
MAP	Mean arterial pressure
MIS	Minimally invasive surgery
PIP	Peak inspiratory pressure
SV	Stroke volume
SVR	Systemic vascular resistance

Introduction

Endoscopic and minimally invasive surgery (MIS) in urology, by both robotic and pure laparoscopic techniques, affords many benefits when compared to open surgery. These benefits include smaller incisions, less postoperative pain, and earlier oral intake, discharge home, and return to normal function [1–4]. Consequently, the applications of MIS are growing, particularly in the field of pediatric urology, where increasingly complex reconstructive procedures are being performed for smaller children.

While many benefits of MIS are proven, these technologies introduce unique physiologic considerations when compared to their traditional open counterparts. In pediatrics, these effects should not be directly extrapolated from the adult data, since children of varying sizes and ages manifest distinct physiologic responses [5]. For instance, compared to adults, children have baseline lower blood pressure and systemic vascular resistance (SVR), while heart rate (HR), oxygen consumption, and cardiac output (CO) are relatively higher [6]. Furthermore, neonates and infants have particularly unique physiologic factors, such as a rate-dependent cardiac output, a propensity to bradycardia, a shorter trachea, lower chest compliance, largely diaphragmatic respiration, and the possibility of persistent right to left cardiac shunts [7]. Hence, the effects of MIS in very young and small children may be even more pronounced [8, 9].

Broadly, the physiologic changes during MIS result from carbon dioxide (CO_2) absorption during insufflation, increased intra-abdominal pressure (IAP), and special positioning requirements. While most of these effects can be controlled with minor modifications in anesthetic management, it is important for the surgeon to understand potential issues to help prevent and manage complications when they occur. In this chapter, we will review the physiologic changes during MIS in the context of pediatric urology. One must additionally consider the option of retroperitoneal insufflation and how its impact may differ from transperitoneal approaches, which will also be reviewed here. The effects of CO_2 absorption, increased IAP, and positioning can either compound or mitigate each other significantly, thus it is vital to note that multiple complex and codependent factors interact to produce the effects described. For simplicity of organization, they are discussed individually below.

Physiologic Response to CO_2 Absorption

The ideal insufflant is noncombustible, has limited absorption and physiologic effects, and rapid excretion when absorbed [5]. CO_2 is currently the gas of choice for most MIS procedures since it is odorless and colorless, has a high solubility in blood, and is readily excreted by the lungs once absorbed [4]. The degree of CO_2 absorption is a function of the insufflation pressure, the surface area exposed to gas, and more importantly, patient factors such as age and weight [10, 11]. CO_2 absorption is greater in children than in adults and appears more pronounced in younger children [4, 12, 13].

Some studies have compared CO_2 absorption during peritoneal and retroperitoneal approaches [14, 15]. General adult studies have suggested more CO_2 absorption during retroperitoneal insufflation and a more prolonged effect after desufflation [16, 17]. These results have been mirrored in pediatric urology, where one prospective study demonstrated increased CO_2 levels for approximately 10 min after desufflation of the retroperitoneum [18]. The most recent prospective study comparing the two approaches in children found that end tidal CO_2 ($ETCO_2$) increases more progressively and gradually during retroperitoneoscopy, unlike the more rapid increase and plateau effect that occurs during peritoneal insufflation [19]. This observation might be explained by the smaller absorptive surface of the retroperitoneum combined with the lack of barrier effect from the peritoneal lining [17, 19].

In healthy children, CO_2 absorption is well tolerated by compensatory mechanisms and ventilatory adjustments [7, 11], but its excess or uncompensated absorption can lead to metabolic disturbances, such as a decrease in serum pH levels, as well as neurologic, respiratory, and cardiovascular effects. These are summarized which are summarized in the subsequent sections [5].

Neurologic

Hypercarbia causes hemodynamic changes in the brain, such as cerebral vasodilation, increased cerebral blood flow (CBF), and increased intracranial pressure (ICP) [5]. These effects are only partially reversed with anesthesia-induced hyperventilation [4]. When $ETCO_2$ is kept relatively constant, CBF still increases, suggesting an additional neurohormonal factor [20]. Karsli et al. found that the middle cerebral artery blood flow velocity increased proportionally to the mean arterial pressure (MAP) and $ETCO_2$ during the first 8 min of pneumoperitoneum, while HR remained the same [19]. After 20 min, $ETCO_2$ continued to increase, whereas the middle cerebral artery blood flow velocity and MAP reached a plateau and then decreased progressively. Conversely, during retroperitoneoscopy, both CBF velocity and $ETCO_2$ increase progressively throughout the procedure but show

parallel decreases towards baseline within 5 min of desufflation. It therefore seems that CBF and $ETCO_2$ increase more gradually during retroperitoneal insufflation, compared to the more rapid increase and plateau effect observed during pneumoperitoneum. It is hypothesized, again, that this is due to the smaller absorptive surface of the retroperitoneum and absence of the peritoneal barrier which induces the plateau effect eventually [19]. These changes may have no clinical sequelae except in long cases, where the anesthetist and the surgeon should be aware of differential absorption rates depending on the approach.

Respiratory

Absorbed CO_2 imposes an increased load on the respiratory system also, where hypercarbia and respiratory acidosis can result. $ETCO_2$ is often used as a surrogate measure of absorbed CO_2. Increases in $ETCO_2$ are noted up to 33 % over baseline values despite ventilator adjustments in one study examining both thoracoscopy and laparoscopy in neonates [4, 8]. To clear excess CO_2 and maintain normocarbia, minute ventilation may need to be increased by up to 50–75 % along with intermittent positive pressure ventilation [7]. Studies in neonates found that an increase of 22.6–40 % in minute ventilation with positive airway pressure was needed to help restore normocarbia [8, 21]. Indeed, Bannister observed that 95 % of patients required at least one ventilator adjustment during surgery to restore $ETCO_2$ to within 10 % of their baseline value [2].

During prolonged procedures, large amounts of CO_2 are also buffered in the muscle and fat, which must be eliminated by the lungs postoperatively [7]. Respiratory acidosis can persist postoperatively in conditions of poor respiratory function or when respiratory drive remains suppressed [7]. Overall, however, when compared to traditional open surgery, the postoperative respiratory benefits of MIS, such as improved rates of extubation and shorter chest physiotherapy requirements, likely outweigh the physiologic changes observed during laparoscopy [3].

Cardiovascular

CO_2 absorption independently influences cardiac function with its direct depressive effects on the myocardium and secondary effects mediated by the autonomic nervous system. In adults, catecholamine release helps maintain CO by increasing HR and stroke volume (SV), which counteracts the effects of increased IAP [5, 22]. Hypercarbia similarly counteracts some of the effects of increased IAP by decreasing SVR and potentiating tachyarrhythmias, unlike the possible bradycardia that can occur with insufflation [7, 22]. Overall, these changes are well tolerated, and the compensatory ability improves with increasing age and size of children.

Physiologic Response to Increased Intra-abdominal Pressure

Pneumoperitoneum is a critical component to MIS techniques. Generally, children have increased abdominal wall laxity compared to adults, and lower insufflation pressures are often required [23]; however, working space remains limited by virtue of their more compact anatomy. While pneumoperitoneum facilitates surgery by expanding the working cavity, it has several physiologic effects resulting directly from the increase in IAP.

Neurologic

Increased IAP may affect the perfusion dynamics of the brain by causing a prompt and sustained increase in intracranial pressure (ICP) due to decreased jugular venous return. This finding is enhanced by the vasodilatory effects that occur with CO_2 absorption. Intracranial venous stasis causes decreased resorption and drainage of cerebrospinal fluid, thereby increasing ICP further. Overall, these effects are proportional to the degree of IAP [4].

Two animal studies have evaluated the effects of increased IAP on ICP [24, 25]. Josephs et al. found that at an IAP of 15 mmHg, ICP increased from 13 to 18.7 mmHg, independently of arterial pH and CO_2 levels. Bloomfield et al. found that an IAP of 25 mmHg increased ICP from a mean of 7.6–21.4 mmHg. Cerebral perfusion pressure fell from 82 to 62 mmHg but was partially restored with volume expansion. The implications of these findings in normal children are unclear, but extra caution should be used in conditions of decreased intracranial compliance, such as head injuries and ventriculoperitoneal (VP) shunts.

In otherwise healthy children, VP shunts are not currently considered an absolute contraindication to pneumoperitoneum [4]. If there are presumed risks in this population, such as shunt malfunction, infection, retrograde flow, or pneumocephalus, then protective means that include clamping or exteriorizing the shunt, shielding the shunt in an endoscopic bag, or regular exsufflation with pumping of the reservoir may be implemented [26–29]. Uzzo et al. advocated invasive ICP monitoring techniques and intermittent drainage of cerebrospinal fluid in their description of two pediatric cases of laparoscopic bladder autoaugmentation [30]. However, the need for such techniques in healthy children with VP shunts has been questioned by others [31]. The largest series of 18 patients with VP shunts in the pediatric urology literature showed no increased clinical sequelae during major and reconstructive MIS procedures [31]. These authors suggest that the risk of invasive ICP monitoring and shunt manipulation might actually outweigh any presumed benefit and recommended routine anesthetic care as the gold standard for this population.

Data on the infection rates during laparoscopy in children are scarce. One of the largest reviews of various pediatric procedures showed no statistically significant

difference in shunt infection rates when comparing open to MIS approaches [32]. With regard to the potential mechanical tubing malfunctions that may occur due to increased IAP, in vitro testing has shown that the one-way valve mechanism of the VP shunt can withstand simulated pressures of up to 80 mmHg without structural distortion [33]. More recently, testing of various VP shunt tubing mechanisms with simulated pneumoperitoneum showed no reflux during insufflation pressures of up to 25 mmHg when the tubing was filled with saline, which simulated the more realistic scenario of a functioning shunt flowing with CSF [34]. In addition to the descriptions above, a number of case reports and series have described successful laparoscopy in this population without complication, and MIS is generally considered safe and feasible with heightened awareness from the surgeon and anesthetist [26, 35–38].

Respiratory

The magnitude of respiratory changes from increased IAP correlates directly with the degree of pneumoperitoneum [2]. With rising IAP, the diaphragm and mediastinum are displaced more cephalad, and chest excursion is restricted. This results in decreased functional residual capacity (FRC), decreased total lung compliance, increased peak inspiratory pressure, and decreased tidal volume (TV) [4, 5, 39]. As such, the ventilation perfusion mismatch expected in routine mechanical ventilation is enhanced, and atelectasis, oxygen (O_2) desaturation, and hypercarbia can occur [2]. These effects are more pronounced in smaller children and neonates with an already low FRC and high oxygen consumption [21]. In healthy children, these changes usually have no clinical sequelae and can be counterbalanced by anesthetic adjustments. Indeed, the large majority of infants require at least one intervention by anesthesia to restore baseline TV and end tidal CO_2 ($ETCO_2$) [2].

With regard to retroperitoneal MIS, peak inspiratory pressures increase upon retroperitoneal space insufflation, with a resultant increase in respiratory rate and decrease in O_2 saturations [12, 40]. In their prospective evaluation of 18 children undergoing retroperitoneal laparoscopy, Lorenzo et al. found that while there was a statistically significant increase in airway pressure during retroperitoneal insufflation, there was a strong trend towards normalization after completion of the procedure [18].

Cardiovascular

The cardiovascular effects of increased IAP are complex and depend on the interplay between preload, systemic vascular resistance (SVR), and cardiac contractility [4]. Positioning and hypercarbia also independently influence these

factors, and consequently the prevailing combined circumstances determine the response in each patient.

The magnitude of effects on cardiac preload is IAP dependent, where 10 mmHg can augment preload by displacing blood from the splanchnic circulation [1]. As pressures increase up to 10 mmHg, heart rate (HR) and mean arterial pressure (MAP) increase, and cardiac output (CO) is maintained. As IAP approaches 15 mmHg, compression of the vena cava occurs, resulting in a decreased preload. Further increases in IAP lead to aortic and splanchnic compression, increasing afterload, which eventually decreases CO [5]. MAP, however, is usually maintained due to increasing SVR [4, 41]. In hypovolemic states, the transition to decreasing CO occurs at even lower IAPs [22].

In neonates and infants less than 4 months of age, IAP of 6–8 mmHg has been reported as a safe level at which cardiovascular derangements are avoided or manageable [4, 13, 21]. Some have reported even higher levels of IAP with stable cardiovascular parameters in this age group [42], but we recommend an IAP of 6–8 mmHg in this patient population.

With retroperitoneal insufflation, the cardiac effects are similar and dependent on pressure [5]. Lorenzo et al. demonstrated a rise in MAP, similar to peritoneal insufflation, but without a significant change in HR when a retroperitoneal pressure of 12 mmHg was used in 18 children (mean age and weight, 79.4 months and 26.7 kg) [18]. These changes showed a trend towards returning to baseline values at the completion of laparoscopic intervention.

Overall, these changes are well tolerated in the healthy pediatric patient with normal cardiovascular function [1, 41]. However, even in healthy patients, vagally mediated reflex bradycardia can occur on insufflation and is most pronounced in smaller children [1]. Additional care must be taken in those with decreased cardiac contractility or congenital heart disease, where excessive IAP can reopen intracardiac shunts and increase the risk of heart failure [43, 44].

Renal

Insufflation of the abdominal cavity can cause oliguria and even anuria, likely due to renal vein compression rather than decreased cardiac output or ureteral compression [45, 46]. It is also suggested that direct parenchymal compression can account for the decreased GFR observed during pneumoperitoneum [47]. Changes can be noted at pressures of 10–15 mmHg, and the decrease in creatinine clearance can persist for up to 2 h after desufflation [45, 46].

Oliguria may also be an age- and time-dependent phenomenon. One study prospectively monitored hemodynamic and renal parameters before, during, and after laparoscopy in 30 children with normal renal function. They found that all patients developed oliguria within 45 min of insufflation at an IAP of 8 mmHg [48]. Anuria developed in 88 % of children less than 1 year of age, compared to only 14 % of those over 1 year of age. No significant changes in serum creatinine and electrolytes

were noted within the first 24 h postoperatively. The decrease in urine output was found to be completely reversible, with volumes increasing after the 4th hour postoperatively. For this reason, it has been suggested that aggressive hydration does not prevent oliguria and can cause adverse effects, especially in neonates and small children [13].

There is a paucity of literature documenting the renal effects of retroperitoneal insufflation. One study suggested that the smaller working space may adversely affect lower pole renal perfusion in children <1 year undergoing laparoscopic retroperitoneal heminephrectomies [49].

Physiologic Effects and Patient Positioning

In addition to the possible physiologic changes that occur with CO_2 insufflation and increased IAP, there are some additional considerations when special positioning is required to optimize visualization. Exaggerated forms of the flank, Trendelenburg, reverse Trendelenburg, or prone positions are often indicated to access the kidney, pelvis, and retroperitoneum, respectively. As with open surgery, pressure points must be padded appropriately, but further issues arise with MIS techniques for pediatric urology.

The Trendelenburg position, even in the absence of pneumoperitoneum, can decrease lung compliance by 17 % and increase peak inspiratory pressure (PIP) by 19 %. Adding 12 mmHg of IAP further decreases compliance and PIP by 27 and 32 % compared to baseline [4, 50]. As a general guideline, adverse respiratory changes are amplified with the head-down position, while with the reverse Trendelenburg position, adverse cardiac effects are magnified due to decreased venous return and compromised CO [5]. The right and left flank positions also may have unique effects. Halachmi et al. observed a greater increase in $ETCO_2$ with the left lateral decubitus position when compared to the right [40]. Finally, in any exaggerated position, the endotracheal tube can easily be displaced into the main stem bronchus, particularly in children where tacheal distances are markedly smaller than adults.

Other Physiologic Effects of MIS

Hypothermia

When compared to open surgery, laparoscopy is associated with decreased insensible losses, but it may result in hypothermia. This hypothermia is due to cold dry gas flow, third space and evaporative fluid losses, and it may be more pronounced in smaller children and during high-flow insufflation [5, 8]. It is therefore recommended to keep gas flow less than 0.2 l/min and consider warmed and humidified

gas insufflation [5, 51]. The risk of hypothermia is also correlated with the length of the procedure [8]. Using linear regression analysis, Kalfa et al. estimated that the perioperative temperature loss in degrees Celsius is 1 % of the surgical time in minutes.

Capnothorax and Embolism

CO_2 embolism is rare but most commonly occurs during initial insufflation or tissue/vascular dissection [51]. It is characterized by a sudden increase in $ETCO_2$ and a decrease in blood pressure and oxygen saturation and classically with a "mill wheel murmur" [52]. If unrecognized, cardiac arrest can result. The initial management maneuvers include stopping insufflation, 100 % inspired oxygen, placing the patient in the lateral decubitus and reverse Trendelenburg position, and aspirating from a central line if available.

Pneumothorax is a rare but reported event in pediatric MIS. It may result from rapid and high insufflation pressures, direct injury to the pleura, or unrecognized congenital diaphragmatic or pleuroperitoneal defects [4, 51]. Some may be subclinical and even small pneumothoraces can occasionally be managed conservatively [53, 54]. A large, non-resolving or tension pneumothorax requires timely evacuation of gas with chest drain placement [54, 55].

Subcutaneous Emphysema

Subcutaneous emphysema is quite common and usually obvious after preperitoneal insufflation or towards the end of a lengthy procedure. It results in a more gradual increase in $ETCO_2$, while other vital signs remain unaffected. Mild and localized emphysema is largely harmless [51]. One must rule out a pneumothorax, which can also present with subcutaneous emphysema. The surgeon should check port sites for displacement and consider lowering insufflation pressures if it is noted.

Summary and Conclusions

Neurologic, cardiovascular, respiratory, and renal effects of MIS result from a complex interplay between increased IAP, hypercarbia, and positioning techniques in addition to individual patient factors. In very small children or those with complex medical issues, one must weigh the numerous advantages of MIS against the potential risk. Overall, the physiologic effects of MIS are well tolerated in healthy children of almost all ages, and indeed, the overwhelming majority of studies have found it safe in the pediatric urology setting.

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Chapter 5
Learning Curves, Costs, and Practical Considerations

Thomas S. Lendvay and Pasquale Casale

Abstract Robotic and conventional laparoscopic technology and applications have penetrated pediatric urology over the last 15 years. Understanding the realities of the ability to learn these technologies, how much they cost, and what information can be disseminated to all fledgling minimally invasive surgeons and programs is vital to ensuring optimal patient outcomes. We provide a synthesis of our experience and observations with analysis from the literature about initiating and maintaining a surgical practice adopting new technology.

Keywords Robotics • Simulation • Surgery • Education • Comparative effectiveness • Training • da Vinci • Pediatrics • Urology

Introduction

Pediatric urology has a strong history of surgical innovation. We tend to embrace new technologies at a pace that does not always mirror the adult urologic practice because we are critical about ensuring that hype does not blind us from fact. The adoption of conventional laparoscopic and robotic surgery in pediatrics clearly demonstrates these principles. In the last 5 years, our field has begun publishing experiences with robotic surgery that show a similar adoption path to the initial

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adult robotic surgery experiences of a decade ago. As robotic surgery gains traction, we owe it to our patients and profession to explore the trajectory of robotic surgery learning, the costs related to pediatric programs initiating and maintaining robotic surgery practices, and to disseminate information about the practical considerations of employing robotics so that future clinicians and programs can learn from our early successes and challenges.

Minimally Invasive Surgery Start-Up

Business Plan

The establishment of a fiscally sound model is crucial for establishing a robotic program. Each institution has individual needs and barriers from the direct costs (such as buying the robotic system) and of the associated material, staff recruitment, and/or staff training. The space for housing the robot has to be taken into consideration such as operating room modifications. Recruitment or development of a physician leader for the program is paramount to establish safety guidelines, as well as ensuring that financial and educational metrics are met by oncoming surgeons. The hospital system must evaluate growth potential with market analysis to estimate the impact a new program will have on the institution. The analysis must encompass the captured and non-captured population, the competition, the analysis of reimbursements and payers, and the learning curve of the program participants with its financial impact on day-to-day business. Estimated surgical volume with outcome metrics must be established to ensure patient safety from the very onset of the program. The actual number of cases needed by each institution to be done a year will vary on the overall financial stability of the hospital system.

Hi-tech surgery comes with an initial expensive price tag. The total cost of surgery can be broken into variable costs and the fixed costs. Variable costs take into consideration all expenses that are needed to execute the individual surgical procedure such as disposables used, medications, and sutures. The fixed cost is a combination of the acquisition of the robotic system and the operating room (OR) time needed to run the robotic program. To offset costs, the mathematical model would favor a high-volume program as to maximize reimbursement and patient population capturing in a competitive market to offset the variable and direct costs of running the program.

Team Building

A surgical director with both administrative and a robust surgical experience is essential to the start-up of the program. This individual would oversee the clinical aspect of the program and strategic growth and monitor outcomes, policing the new

surgeons excited to join the program by objective metrics. The surgical director must oversee the training of the entire team.

Contrary to traditional open surgery, robotic surgery implies that the leading surgeon does not have direct contact with the patient being completely immersed in the console; therefore, the OR staff and surgeons in training are typically the ones in direct contact with the patient. A complete understanding of the procedure and the surgical steps is crucial. The availability of having one team for the establishment of the robotics program is critical. The consistency of the team will allow a rapid learning environment where the team can be proficient and safe. Once this team has mastered the nuances of the surgical robot and procedures, they can effectively teach more OR staff to expand the team. The most difficult component is teaching the physicians in training on how to perform these procedures safely and effectively while building the program. It is imperative that the surgical leaders of the program help establish a routine for the OR staff. This may hinder the "hands-on" training needed by residents and fellows. This obstacle becomes easier when the OR team is fully trained, but until then the surgical leaders must ensure that physician training is not compromised.

Marketing

After your institution has made the investment in robotic capital expenses and staff resources to support a robotic surgery program, it is important to let your community know that this patient care opportunity exists. We believe that it is important to market with transparency. Identifying a champion in your respective institution's marketing department who has a particular interest and experience in approaching the community and media about hi-tech innovations is helpful. We found that creating information delivery milestones helped organize our messaging. For example, once you acquire the robotic platform, plan to announce to your community providers that your institution can now offer patients this technology for *some* patients. Include the entire robotic team in any photo opportunities because the success of a program does not solely hinge on the surgeon. Plan to announce to the media when your program has reached patient outcomes comparable to your open practices or when your program has reached certain volume milestones. The former is a very transparent appraisal of your program and resonates well with your community providers; the latter tends to excite the media more because many demonstrations of success in our culture are driven by quantity.

Establishing durability and longevity is vital to building trust in your community. When you reach a chronological milestone (e.g., 5 or 10 years of providing robotic surgical care), organize a media announcement with your marketing colleagues that celebrates this achievement (see accompanying Video 5.1).

If your institution does open houses or gives tours to the community, include a stop at a robotic surgery *station*. In our institution, we annually open our doors to all families in our community to show children what we do. The robotic surgery station where children can sit and manipulate the robotic instruments through a dry lab

module has drawn the biggest lines. And engaging the children who visited our station by a "naming-the-robot contest" added to the fun. The winner was awarded a plaque and airtime with our local media outlets.

Patient Selection/Clinical Ramp-Up

The success of your robotics practice will depend squarely on your patient outcomes. You must expect that there will be challenges when you initiate your program so it is important to identify the ideal patients and families. There are three primary variables to the initial success of robotic surgery: the patient, the team, and the surgeon.

When deciding on the ideal patient, we recommend starting with procedures that you are comfortable doing both open and laparoscopically. School-aged patients with ureteropelvic junction obstruction (UPJO) are probably the most reasonable patients to start with. Patient age is important because very young children may pose some size limitations and have a higher complication rate in some series [1, 2]. Patients with UPJO tend also to have few comorbidities and the anastomotic reconstruction is analogous to open techniques. Simple nephrectomies have also been described in robotic surgery [3, 4] and may also be a good case to begin with, but as your practice expands, we believe that the robotic approach tends to facilitate reconstructive procedures more so than extirpative ones.

When your institution invests in a robotic surgery team, there are two approaches to team design: (1) one or two core teams do all the robotic surgeries or (2) many staffers are trained on the robotic setup so that available nurse and surgical technician schedules do not limit utilization of the robot. In Seattle, our choice was to train as many nurses and scrub technicians as possible to mitigate access to knowledgeable robotic staff. In retrospect, we believe that having more dedicated core teams would have facilitated a more rapid learning curve for the team because we effectively diluted the knowledge. In Philadelphia, the latter approach was used. We found that there is only so much in-servicing you can do to train robotics, and actually doing cases is important to solidify the training. Upon initiating a robotics practice, one can expect to do fewer than 2–4 cases a month/surgeon which does not give your staff much ability to become familiar, especially if not using the dedicated core team approach. One method for amplifying experience is also establishing dedicated time for the entire team (staff, surgeons, anesthesia) to do walk-throughs of actual patient cases such as a left-sided pyeloplasty with cystoscopy and retrograde pyelogram. This mimics the realities of how the room needs to be set up and what roles each team member has and when. In addition, identifying champions within the nursing and technician staff who might be particularly interested in learning and being a part of new technologies was helpful.

Once your institution makes the investment in the program, there is desire to encourage many surgeons to consider learning and applying the technology. We have found that success is accelerated if certain robotic surgeon champions in

your institution are identified first and supported to build a robotics practice. Unlike our adult colleagues who may have over 100–200 appropriate patients a year per surgeon to apply robotic approaches, pediatric urologists may see 25–50 in a year that would be ideal robotic candidates. And much like the difference between core teams and the omni-staff approach, we believe that one or two surgeons establishing their robotics practice are more effective and safer for our patients [5]. In addition, once learning curves are overcome, we have observed innovation within robotic surgery practices [6, 7]. These champions, once comfortable, can then disseminate knowledge to the other members of the practice or other subspecialties within the institution.

Space

Identification of the appropriate operating room space is nontrivial. The only commercially available robotic platform for clinical use has three major components that collectively take up over 30 sq ft. and weigh more than 1,000 lbs altogether. There are two philosophies to creating an environment for ease of robotic flow: (1) identify one or two rooms that become the robotic surgery suites or (2) utilize the mobility of the robot (each component is on castors) and move the robot to whichever room needs it. We have taken the approach of maintaining the platform in one of our bigger operating rooms (590 sq. ft.), and we adjust the surgical subspecialty and block time based on the robotic requirement. We have found that this obviates the need to build setup time for transporting the robot itself. In addition, within the room in which the robot in housed, we went from moving the robot to the patient to moving the patient bed to the robot (Fig. 5.1).

For example, when doing left- or right-sided pyeloplasties, we keep the three robotic components in roughly the same floor position and rotate the bed 180°. Initially this created some consternation among the anesthesia team as the head of the patient was now away from the ventilator and anesthesia station. This apprehension was alleviated through dry lab drills simulating this orientation. We found that the bed rotation approach allowed our staff to prep and drape the robot in advance of the patient entering the room.

Learning Curve

As with any new technique or approach, there is an inherent learning curve [8, 9]. Taking steps to accelerate learning curves through identification of early champions; managing expectations; creating preliminary milestones; being forthright with your patients, your nursing staff, and your administration; and understanding the realities of what others have shown with regard to the robotics learning curve will facilitate success in your robotics program.

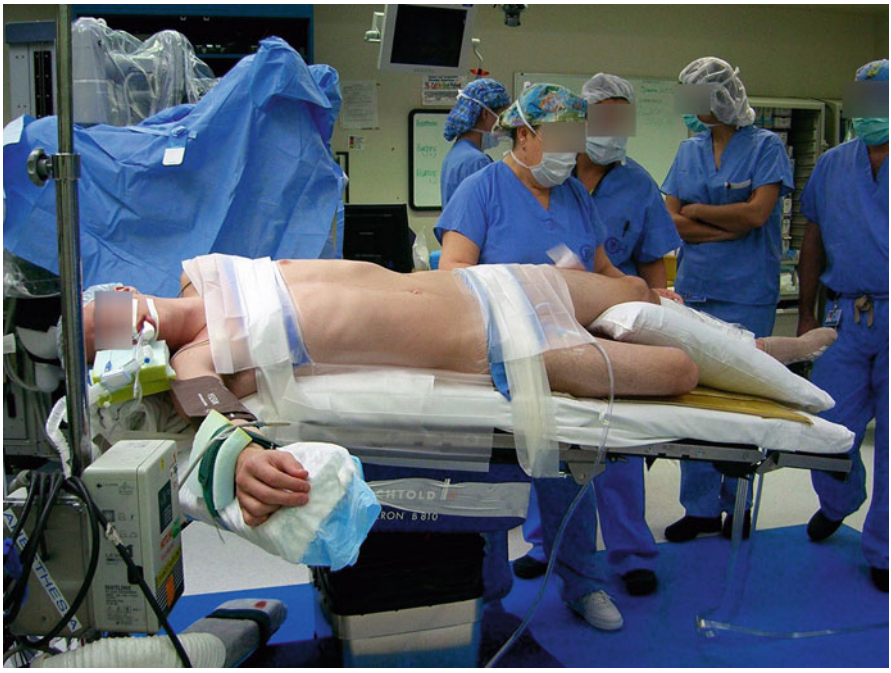

Fig. 5.1 Patient positioning for left-sided pyeloplasty with bed turned towards the robot

Subspecialty Participation

Pediatric urologists will most likely be the largest adopters of robotic technology in your institution followed by general surgery. We believe that starting with these two surgical disciplines will yield the fastest and safest ramp-up in the program. Cardiac and otolaryngologic pediatric surgeries are now starting to utilize robotics [10, 11], but unless your institution has a member from one of these specialties with existing sound robotic experience, we recommend starting with urology and general surgery teams. There is also ample crossover among the nursing and scrub technician staff between urology and general surgery as our equipment needs, cavity of approach, and target organs are frequently identical. Once your institution has identified one or two starting services, we recommend identifying clinicians who have a strong background in conventional laparoscopy [5]. These champions tend to be more familiar with laparoscopic access, approach, and equipment which are analogous to robotics. There are many examples of surgeons who have become quite facile in robotics with minimal conventional laparoscopic experience [12, 13], and ultimately expanding the ability of all providers to offer the robotic approach is ideal, but minimizing as many aspects of robotic adoption that may be foreign to the starting roboticist is critical for success. It helps to have at least 2 providers in the program at initiation so that (1) communication with your administration and operating room teams can be defrayed and (2) so that idea sharing is possible to accelerate learning and innovation.

Expectations and Milestones

For the classically trained surgeon, the challenge of standard laparoscopy is often overwhelming, whereas transferring the surgical skills in the robotic environment is easier. Laparoscopically naïve surgeons need between 20 and 25 cases to show proficiency [10]. This has also been seen in other works such as a report by Patel et al. that showed a similar learning curve [13]. Unless the surgeon starting a new program is already experienced, there needs to be proper training. This can be accomplished by visiting an already experienced surgeon at their home institution to observe cases. Expert mentoring is also crucial during your first run of procedures to ensure that you are executing all the key maneuvers. Continual video critiquing of your surgical cases is paramount to fine-tune your skills. It becomes most effective when you watch your recorded cases with a colleague who has the same interests as you in robotic surgery.

Following complete training, patient selection is paramount especially early on in program development. Age, anatomy, body mass index, comorbidities, and previous experience with a surgical procedure either in an open or laparoscopic model need to be carefully picked at the beginning of the surgical experience.

Patient Counseling

In our experience, many families are excited about the option of a robotic approach for their children. Honesty is important to help manage expectations when initiating your practice. It will be predictable that despite as much dry lab training and proctoring you receive, in the beginning, your operative times will take longer than your open or even laparoscopic times. In addition, you are not the only ones in the room on his/her learning curve. Your ancillary staff and anesthesia team are also learning, and inconsistency in the teams will amplify operating room times. Tell your patients that you are initiating your robotics practice, and tell your patients if they are one of the first patients in your fledgling experience. Let them decide if they prefer this. We have found that many patients were excited to be the "firsts," while other families were more apprehensive. Giving the families information about how your outcomes compare to the literature sends a strong message about your integrity and your appreciation for the trust that the families place in you.

Learning Curve Tracking

In early reports of incorporating robotic surgery into one's practice, outcomes, fortunately, have tracked the open approaches [14]. Sorenson et al. analyzed their first 33 consecutive robotic pyeloplasties among two pediatric urologists and found that length of stay, postoperative pain scores, and surgical outcomes at a

modest follow-up (median 16 months) were analogous between open and robotic approaches. Robotic operative times were consistently longer until a certain threshold of cases (15–20) was approached, whereby operative times fell within 1 SD of the matched open cohort. The majority of this time drop (70 %) was appreciated in the surgical time defined as incision to close. This appraisal showed that the surgeon with a more rapid case volume experience saw a faster drop in his operative times. Complications were clumped towards the initial ten cases and were mostly technical in nature. This study also highlighted the importance of optimal patient selection, a principle not well adhered to by these surgeons. The longest case in the study was a robotic pyelolithotomy and pyeloplasty within the first eight cases of one of the surgeon's overall robotic experience. This study was limited in that it compared the early stages of experience in the robotic approach to the experience of surgeons who had performed the open approach for decades. This is the challenge with appraising comparative effectiveness data because there is virtually no data on the learning curve of open pyeloplasties.

Tasian et al. collected the surgical console times in 20 consecutive robotic pyeloplasty cases of four pediatric urology fellows when they performed 75 % or more of the console time [15]. The console times were compared to 20 consecutive robotic pyeloplasty cases where the attending alone performed 100 % of the console time. All times were validated post procedure by viewing the surgical video and confirming times of console switching. They only evaluated console time. Positioning, prepping and draping the patient, obtaining laparoscopic access, and wound closure were excluded due to participation of other team members. They found the mean console time for the attending operating alone was 54 min. The operative times for the cases in which the fellow performed 75 % of the case decreased with increasing number of cases done (Fig. 5.2).

Assuming the trend of increasing efficiency continues at the same rate, operative times for fellows were projected to be equal to that of the attending urologist once 42 cases have been performed. In their series, all pyeloplasties were successful as demonstrated by postoperative radiologic improvement, and there were no complications (Fig. 5.3).

Future Thoughts

There are opposing forces to how we can provide safe, effective, and cost-responsible care for our patients. On the positive side, more trainees are graduating from residencies and fellowships with robotic experience. This is markedly better than the original generation of robotic pediatric urologists who were mostly self-taught. Furthermore, more operating room staff and anesthesia teams are familiar with robotic surgery. On the negative side, restricted trainee duty hours and nonstandard training and credentialing protocols for robotic surgery threaten to undermine our goals of success.

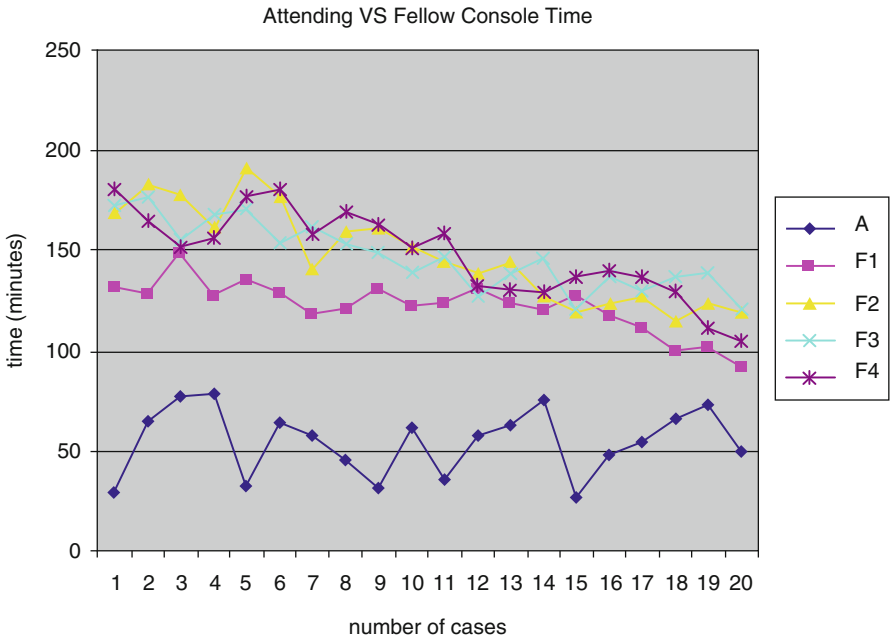

Fig. 5.2 Fellow console time consistently decreased by doing more cases

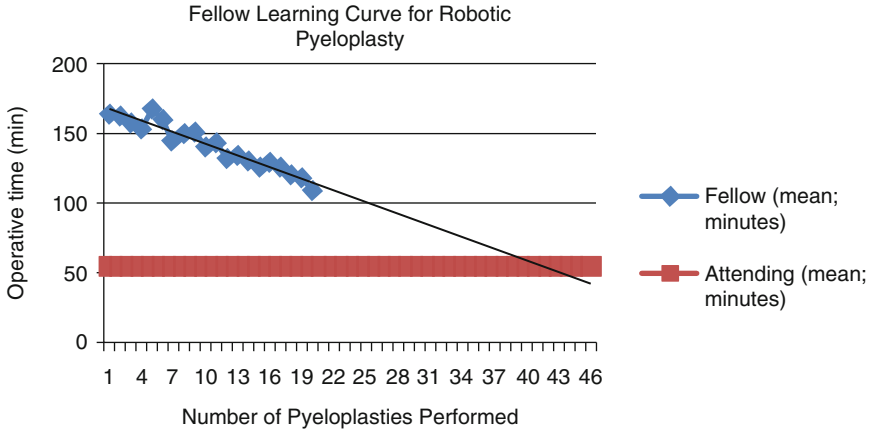

Fig. 5.3 Downward trend of operative times of fellow approaching senior surgeon

Education

Recognizing that our ability to train learners in the operating room setting on live patients has been curtailed, we have an opportunity to standardize training outside of the operating room for our learners (both surgeons and staff). The use of simulation

education is standard in many surgical practices [16], but is spotty in robotic surgery. Curriculum has been validated for discriminating robotic surgery skills [17], and the use of virtual reality simulation has reduced the challenges of having access to the robot itself for training [18, 19]. Efforts are under way to standardize training for all new robotic learners in the United States through the Fundamentals of Robotic Surgery (FRS) initiative [20]. This curriculum promises to remain agnostic to the robotic surgery platform used because it is expected that within the next 5 years, there will be additional commercially available platforms. This standard curriculum will include a cognitive or didactics module and a technical skills module. And similar to the Fundamentals of Laparoscopic Surgery (FLS) curriculum that is required to pass for all general surgery residents before graduation from residency, FRS certification may be required by many surgical boards for allowance to perform robotic surgery.

Future Technology

The estimated market for robotic surgery in 2012 was $2.6 billion [21]. And as patents for the existing robotic technology expire over the next few years, one can expect that a number of medical device and technology start-up companies are and will explore robotic surgery research and development. Our pediatric urology community needs to be involved in this surge in technology development to ensure that our patients' special needs are met. Less expensive equipment, miniaturization of instrumentation, and improved tool-tissue interaction feedback are all areas in which we can drive and demand innovation.

Conclusions

Pediatric urologists have an opportunity to lead robotic surgery initiatives within our hospitals, our training centers, and our medical device partners. Approaching robotic surgery programatically instead of individually enhances your practice and reduces potential challenges. We should strive for effective patient care while minimizing the expense footprint, and to do this, we need to establish standard education pathways, create efficiency goals when starting a robotics program, and be good listeners to all team members involved that have an invested interest in the best healthcare we can provide.

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Chapter 6
Laparoscopic Nephrectomy and Heminephrectomy

Imran Mushtaq

Abstract The minimally invasive approach for the management of benign renal conditions has become a standard technique in pediatric practice. Nephrectomy, heminephrectomy, and nephroureterectomy, by the retroperitoneal and transperitoneal route, are readily available in many centers worldwide. The benefits to the child in terms of a faster postoperative recovery and improved cosmesis are without question.

The retroperitoneal technique avoids colonic mobilization and has a reduced risk of injury to hollow viscera. However, the reversed orientation of the kidney and hilum and the comparatively smaller working space may make this approach difficult to master. The transperitoneal route has the advantage that it can allow a more complete ureterectomy when indicated. Complications from both approaches are uncommon.

Keywords Nephrectomy • Heminephrectomy • Pediatric • Transperitoneal • Retroperitoneoscopic

Introduction

The minimally invasive approach for the management of benign renal conditions has become a standard technique in pediatric practice. Nephrectomy, heminephrectomy, and nephroureterectomy, by the retroperitoneal and transperitoneal route, are readily available in many centers worldwide [1, 2]. Gaur initially described the retroperitoneal approach, which is now the approach of choice for most laparoscopic

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surgeons [3, 4]. However, the transperitoneal route still has a role when performing renal ablative surgery for tumors or when performing laparoendoscopic single-site (LESS) surgery [5, 6]. Regardless of the approach utilized, the benefits to the child in terms of a faster postoperative recovery and improved cosmesis are without question.

Refinements in techniques have now extended the role of laparoscopy in the author's practice for managing end-stage renal disease in children who require bilateral native nephrectomy [7]. These can be performed in a synchronous fashion without breaching the peritoneum followed by insertion of a peritoneal dialysis catheter. Immediate postoperative peritoneal dialysis can be performed, avoiding the need for hemodialysis and its complications.

The Approach

Both the retroperitoneal and transperitoneal approach have been well described, both with their advantages and disadvantages, and the laparoscopic surgeon should be familiar with both techniques. The retroperitoneal technique avoids colonic mobilization, has a reduced risk of injury to hollow viscera, and avoids the potential risk of adhesion formation. However, the reversed orientation of the kidney and hilum with the patient in a semi-prone or prone position combined with the comparatively smaller working space may make this approach difficult to master. Another possible advantage of the retroperitoneoscopic approach is reduced postoperative pain due to the absence of peritoneal irritation by blood and/or urine.

For some procedures involving significant intracorporeal suturing or where previous surgery on the kidney has resulted in scarring/fibrosis, some surgeons may prefer the transperitoneal route, as an example for laparoscopic pyeloplasty. This route allows for a larger working space and facilitates intracorporeal suturing. The choice of approach will also be influenced by the surgeon's experience and training, which may lead to there being one preferred option.

In this chapter, only the retroperitoneoscopic approach will be discussed, as this is the current technique of choice for laparoscopic nephrectomy and heminephrectomy.

Indications and Contraindications

Nephrectomy

A laparoscopic nephrectomy or nephroureterectomy is indicated in the following cases:

1. Congenital renal dysplasia with a poorly functioning or nonfunctioning renal unit
2. Multicystic dysplastic kidneys, which, on follow-up, have failed to involute or are associated with systemic hypertension
3. Pelviureteric junction obstruction with loss of function

4. Reflux-associated nephropathy
5. Intractable protein loss associated with congenital nephrotic syndrome
6. Pre-transplant in children with focal segmental glomerulosclerosis

Heminephrectomy

1. Renal duplication anomalies: an upper pole heminephrectomy is performed most commonly, typically in the setting of hydroureteronephrosis of the upper moiety with reduced or poor function.
2. Renal duplication in girls with ectopic insertion of upper moiety ureter with urinary incontinence and poorly functioning upper pole.
3. Lower pole heminephrectomy: a lower moiety heminephrectomy is performed in reflux-associated nephropathy with loss of function or rarely in cases of lower moiety pelviureteric junction obstruction with loss of function.

Preoperative Workup

1. Recent imaging in the form of a recent renal ultrasound scan and MAG3/DMSA scan must be available.
2. In children with a history of vesicoureteric reflux, the micturating cystogram images must also be available for review.
3. The renal ultrasound provides information about the size of the kidney, degree of hydronephrosis, and in case of a multicystic kidney regarding the number and size of cysts. This allows for deciding the technique for specimen removal, i.e., Endopouch and cyst aspiration.
4. Routine preoperative blood tests, which should include serum creatinine, hemoglobin level, and a group/save of serum. Clotting parameters do not need to be checked routinely, unless there is a history of bleeding disorders.
5. No other specific preoperative patient preparation is necessary.

All children receive single dose of appropriate intravenous antibiotic (the author prefers an aminoglycoside such as amikacin or gentamicin), either prior to leaving the ward or at the induction of anesthesia.

Specific Instrument Required

1. Primary camera port – 6 or 10 mm Hasson, 2 secondary 5 mm ports (the author prefers 5 mm Ethicon Endopath Xcel® trocar)
2. 30° 5 mm telescope
3. Kelly forceps (×2) for dissection
4. Metzenbaum scissors

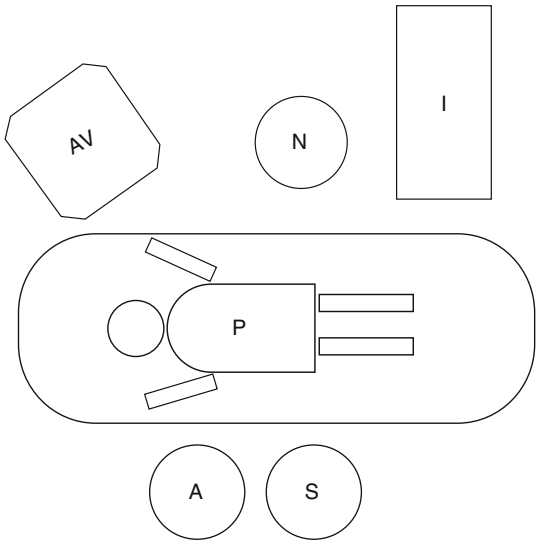

Fig. 6.1 Schematic representation of the room setup (*P* patient, *AV* audiovisual equipment, *N* scrub nurse, *I* instrument trolley *S* surgeon, *A* camera holder)

5. Harmonic scalpel® or Ligasure® for coagulation/division of vessels and renal parenchyma
6. Endopouch for specimen retrieval if large specimen

The patient (P) is positioned prone for the operation. The monitor and stack system (AV) should be placed on the side opposite to the affected kidney, towards the head of the table, with the screen pointing towards the pelvis. The scrub nurse (N) should be positioned adjacent to the laparoscopic stack, with the operating surgeon (S) and assistant (A) both on the side of the affected kidney (Fig. 6.1).

Anesthesia

Endotracheal intubation is required in all cases using either a cuffed or reinforced endotracheal tube, securely fastened. This is to prevent tube dislodgement when the child is positioned prone for the surgery. Perioperative and postoperative analgesia is provided by preemptive local infiltration of the planned incisions with 0.25 % bupivacaine.

Operation

Retroperitoneoscopic Nephrectomy (Video 6.1)

1. The patient is positioned fully prone under general anesthesia. Other approaches including the lateral and anterolateral approach are also popular. The exposed dorsal and lateral aspects of the trunk are prepared and draped in a sterile manner. Topographic landmarks and anticipated port sites are marked as shown (Figs. 6.2 and 6.3).

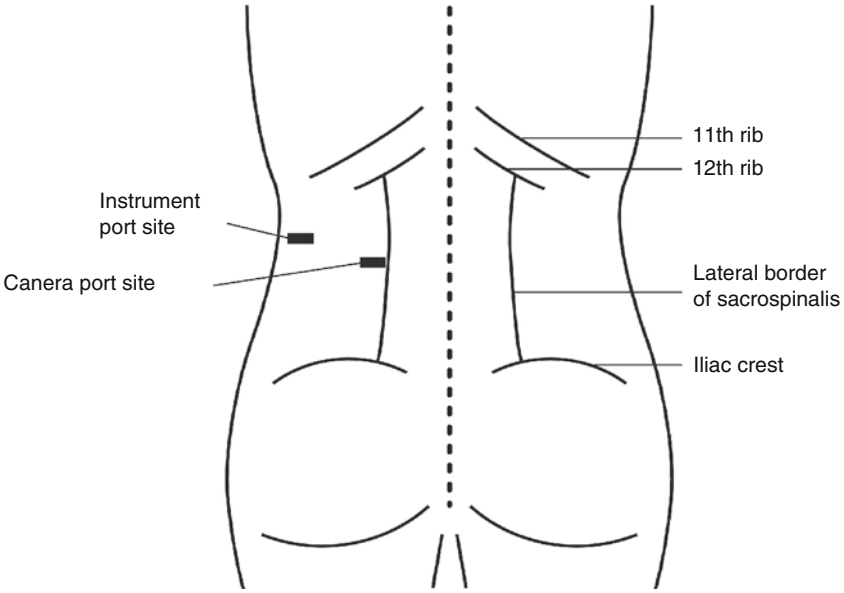

Fig. 6.2 Schematic representation of port position

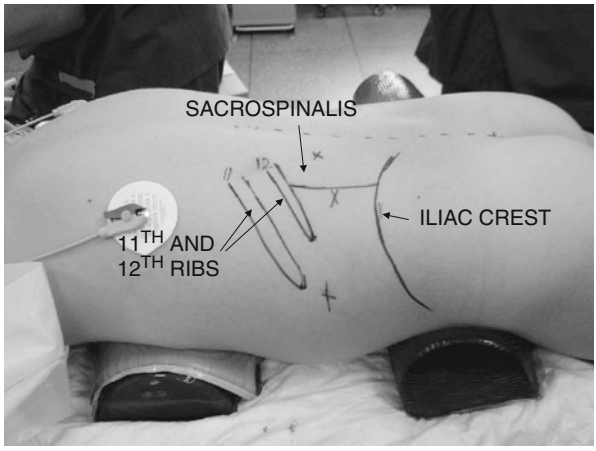

Fig. 6.3 Preoperative demonstration of landmarks and port sites

2. Creation of retroperitoneal space outside Gerota's fascia by a technique described by Gill [8]. Several commercial balloons are available for creation of the retroperitoneal space. However, the author prefers a simple and inexpensive balloon made by securing the finger of a sterile surgical glove to the end of a 12 Fr Jacques catheter with a silk tie. The catheter is connected to a 3-way tap and a 50 ml luer-lock syringe. Depending upon the size of the patient, 100–250 ml of air is injected slowly to develop the retroperitoneal space. The system is left inflated for 2 min to promote hemostasis and then deflated and withdrawn.

3. Insertion of primary and secondary ports: a 6 mm Hasson cannula is inserted into the port site, followed by insufflation of the retroperitoneum with CO_2 to pressure of 10–12 mmHg. The Hasson port is secured by a suture to the skin. A 5 mm instrument port is placed under direct vision below the tip of the 11/12th rib and above the iliac crest. A second working port (5 mm) can be placed through the paravertebral muscles although in the author's experience the nephrectomy can be performed using a single working port [9, 10].
4. Exposure of the kidney: Gerota's fascia is incised longitudinally adjacent to the posterior abdominal wall using scissors. The adventitious tissue is divided to gain adequate exposure and working space for the procedure.
5. Exposure of the hilum: the kidney is dissected commencing at the apex and along the medial aspect. The lateral and inferior attachments are not divided at this stage as they anchor the kidney in position and aid in exposure of the hilar vessels.
6. Division of the vascular pedicle: the vessels are divided between hemoclips or with a Ligasure® when the vessels are less than 8 mm in diameter. A minimum of three clips should be applied on all vessels, with at least two clips remaining behind on the proximal stump of the divided vessel.
7. Ureteric division: the ureter is traced as far into the pelvis as is necessary. In cases of reflux-associated nephropathy, the ureter may be ligated with an endoloop or transected without ligation and the bladder drained with a urethral catheter for 48 h.
8. The remaining attachments of the kidney are divided using a combination of blunt dissection, monopolar diathermy, and/or the Ligasure®. In the case of a large multicystic dysplastic kidney, complete intracorporeal mobilization can be technically difficult and time-consuming and risks creating a tear in the closely attached peritoneum. In such cases, after all vessels have been divided and the cysts decompressed, the kidney can be withdrawn via the camera port incision and the remainder of the dissection completed in an extracorporeal manner.
9. Specimen retrieval: the specimen may be removed via the camera port depending upon the size. A multicystic dysplastic kidney or hydronephrotic kidney may be decompressed by aspiration and withdrawn directly via the camera port wound. A larger specimen may be retrieved after engaging it in a 10 mm Endopouch retrieval device and removing it piecemeal with sponge forceps.

Retroperitoneoscopic Heminephrectomy (Video 6.2)

The room setup, patient positioning, and the steps for surgical access are the same for a retroperitoneoscopic heminephrectomy as they are for a retroperitoneoscopic nephrectomy. In particular the position of the patient and the port sites are identical. This applies whether an upper or lower pole heminephrectomy is to be performed.

10. Exposure of the kidney: the kidney is exposed as for a nephrectomy. It is essential from an early stage to clearly visualize both moieties of the duplex system, especially both ureters.

11. Ligation of vessels: the vessels supplying the affected moiety are individually identified and divided between clips or with a Ligasure®. In some cases the polar vessels will be clearly evident, while in other cases there will be short segmental vessels originating from the main vessels close to the renal hilum. The latter scenario is seen more frequently when the affected renal moiety is small and dysplastic.
12. Isolation of ureter: the ureters from the affected and unaffected moieties are identified. The affected ureter is transacted just distal to the pelviureteric junction, and this stump is used for traction to rotate the kidney and identify any further vessels, which are then divided.
13. The devascularized moiety will now be evident as an area of hypoperfusion. The renal capsule is scored with monopolar diathermy at the junction between the two moieties.
14. Resection of affected moiety: the affected moiety is encircled with a 3/0 Vicryl endoloop, using the proximal end of the divided ureter as counter traction. The ligature is firmly tightened at the junction between the renal moieties. The parenchyma is transacted with hook scissors 5–10 mm distal to the ligature. An alternative technique to remove the affected moiety is to transect the parenchyma with a Harmonic scalpel® or Ligasure®.
15. The distal ureteric stump is traced down as far as is necessary in the pelvis taking great care to isolate and preserve the normal ureter. The ureter is ligated when there is associated reflux prior to transaction.
16. Specimen retrieval: the specimen can be extracted directly through the camera port incision in the majority of cases. Larger specimens are extracted with the use of a 10 mm Endopouch specimen retrieval device. The wound is closed in layers, without the use of a drain.

Postoperative Management

1. Can start fluids and diet on return to the ward.
2. Close observation for the possibility of hemorrhage.
3. As bacteremia may occur during the procedure, oral antibiotics to cover the immediate postoperative period may be required in some cases.
4. The patient is discharged when mobilizing with adequate control of pain with simple analgesia.

Complications

Peritoneal Tear

The posterior prone approach minimizes the risk of a peritoneal tear as compared to other approaches for retroperitoneoscopic surgery. It can occur in the following situations: dissecting balloon is inflated too rapidly; the balloon is too small for the size of the patient, in adolescent children, and in children on peritoneal dialysis.

Balloon Rupture

Rupture of the dissecting balloon can occur when the balloon is inflated too rapidly, with over-inflation of the balloon or when excessive external pressure is applied over the balloon. When it occurs the ruptured balloon must be carefully examined for lost fragments, which should be sought and removed from the patient.

Intraoperative Bleeding

Intraoperative bleeding is most likely due to slipping of hemoclips from a renal vein or due to inadvertent damage to a renal vein or vena cava by a laparoscopic instrument. In most cases, hemorrhage can be controlled by the prompt application of hemoclips to the affected vessel. Uncontrollable hemorrhage will require conversion to an open approach to ligate or over sew the bleeding vessel.

Urine Leak

A retroperitoneal urinoma can occur from the reflux of urine from the distal ureteric stump or from the cut surface of the kidney following heminephrectomy. The risk can be kept to a minimum by the use of an endoloop suture on the renal parenchyma and by endoloop ligation of refluxing ureters as opposed to the use of hemoclips or the harmonic scalpel to seal the ureter. Most urinomas will resolve with the placement of a urethral catheter for at least 48–72 h. A persistent urine leak or an infected urinoma may require the placement of a percutaneous wound drain.

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Chapter 7
Laparoscopic Pyeloplasty

Francisco J. Reed and Pedro-José López

Abstract Dismembered pyeloplasty is the gold standard surgery for resolution in a pelviureteric junction (PUJ) obstruction. Laparoscopic pyeloplasty is gaining worldwide acceptance, with a similar success rate as the open technique. However, laparoscopic pyeloplasty is one of the most demanding minimally invasive surgeries in pediatric urology. In this chapter we explain step-by-step the surgical protocol that we use in our unit, with some trends in minimally invasive surgery performed around the world. We hope that this chapter would be a handful instrument for those who would like to develop this technique as well as the following generations in their development as pediatric urologists.

Keywords Laparoscopic pyeloplasty • Pediatric • PUJ obstruction

Introduction

Currently the gold standard surgery for pelviureteric junction (PUJ) obstruction is the Anderson-Hynes dismembered pyeloplasty, with a success rate greater than 95 %. With the advent of minimally invasive surgery (MIS), there is an increasing role for the laparoscopic approach to performing this operation. Kavoussi and Peters described the first laparoscopic pyeloplasty in children [1], and 3 years later, Tan

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described the results in the first series of six pediatric patients [2]. In the last decade, laparoscopic pyeloplasty has produced success rates similar to the open approach, although the operative time remains somewhat greater.

Nowadays, transperitoneal access is the most popular laparoscopic approach for this operation, as it provides a large and bigger working space in which to manipulate the instruments and perform the anastomosis. Retroperitoneoscopic access will also be described, but it is less popular because of its limited working space.

The most criticisms for laparoscopic pyeloplasty are the difficult and demanding intracorporeal suturing which results in a prolonged operating time, and the slow learning curve. Robotic technology, available since the early 1990s, has addressed some of these criticisms. The robotic device, with a range of movements comparable to the human wrist, allows a non-experienced laparoscopic surgeon to perform difficult tasks with great precision and accuracy.

Robotic equipment, such as the da Vinci system (Intuitive Surgical, Sunnyvale, California, US®), costs almost €1 million and requires a spacious operative theater as a result of its bulky components. Future refinements of these systems and the associated technology hold the key to further evolution of MIS in pediatrics [3].

At present, there is a surgical dispute for better cosmetic outcomes and/or for making minimally invasive surgery "even more minimally invasive." Therefore, techniques like NOTES (natural orifice transluminal endoscopic surgery) [4], LESS (laparoendoscopic single-site surgery) [5], SILS (single-incision laparoscopic surgery) [6], and HIdES (hidden incision endoscopic surgery) [7] are being described for pyeloplasty. From a review of the published results of these techniques, it seems that HIdES is comparable with the transperitoneal route, as it does not require special instrumentation or has any added technical pitfalls.

Indications

For the authors, laparoscopy is just a different approach for the same surgery; thus, indications for laparoscopic pyeloplasty are similar to those for open surgery:

- Symptomatic PUJ obstruction (pain, infection, palpable mass)
- Worsening hydronephrosis
- AP diameter of >20 mm with calyceal dilatation and/or renal function <40 %
- AP diameter >30 mm

The authors' preference is to offer a laparoscopic pyeloplasty primarily to the teenage group but also to suitable children weighing over 5 kg. The reasons include the following: (1) the older child provides a larger intraperitoneal working space for suturing; (2) in infants <5 kg, there is no significant difference in terms of pain and recovery to normal activity between the laparoscopic and open approach; and (3) in teenagers the incidence of crossing vessels is higher, and the vascular transposition may be an alternative to the more traditional dismembered pyeloplasty [8].

Strictly speaking, there are no formal contraindications to this procedure. Nevertheless, there are situations where the surgeon has to evaluate the feasibility

of the laparoscopic approach within his or her own spectrum of expertise. Relative contraindications may include previous abdominal surgery (where retroperitoneal approach might be preferred), redo pyeloplasty, and a small intrarenal pelvis. The robotic-assisted pyeloplasty may facilitate redo surgery [9].

Investigations

Diagnosis of PUJ obstruction is traditionally based on an ultrasound scan and isotope renography (MAG3). Severity of hydronephrosis, thickness of renal parenchyma, kidney function, and drainage of the kidney are all assessed.

In anatomical variants, such as a horseshoe kidney or possible lower pole crossing vessels, an intravenous urogram (IVU) or magnetic resonance angiography (MRA) may be useful. In some instances, bowel preparation 24 h before surgery, especially for a left-sided laparoscopic pyeloplasty, may be useful.

Instrumentation

Camera-video system
1 30° 5 mm laparoscope
3 and 5 mm laparoscopic instrument set which contains
1 6 mm Hasson port
3 ports for 3 and 5 mm instruments

- 1 port for 3 mm instrument
- 2 Kelly forceps
- 1 bowel grasper
- 1 Manhes grasper
- 1 right angle dissector
- 1 Metzenbaum scissor
- 1 pyeloplasty scissor
- 1 diathermy hook
- 1 needle holder (3 mm)
- 1 suction/irrigation device

Long 19 Fr Teflon cannula
3.7–5.2 Fr 8–20 cm multi-length silicone double-J stent and guidewire

The da Vinci robotic system (Intuitive Surgical, Sunnyvale, California, USA®) has three components:

1. The endoscope and robotic arms mounted on a pedestal
2. The surgeon's console with a 3D-HD monitor and manipulator controls
3. The control tower with an extra 2D monitor

The robotic instruments include needle holder with scissor in the back, graspers, round tip scissors, bipolar forceps, and harmonic scalpel. Currently these instruments are 8 and 5 mm; nevertheless, 5 mm instruments are not the most used in small children as the instrument wrist is longer [10].

Operative Technique (Video 7.1)

1. Under general anesthesia, the patient is positioned in a lateral decubitus position, approximately in 60–75º with the affected kidney at the top of surgical field. The patient is secured with adhesive tapes.
2. Patient is positioned facing surgeon and placed to the edge of the operating table, or with sand bags, in order to expand the renal fossa of the hydronephrotic affected kidney.
3. Patient is positioned facing surgeon and placed to the edge of the operating table, at an approx. 70º inclination or tilt. This facilitates free movements of the instruments. The laparoscopic stack system with the screen should be placed opposite to the surgeon, at the back of the patient, making one line (surgeon-patient stack). Schematic diagram of theater layout with position of personnel and stack as well as patient position is shown in Figs. 7.1 and 7.2.
4. First port is placed by an open technique (Hasson) in the region of the umbilicus and secured with a skin suture. The gas flow is set at 2–4 L/min and the abdominal pressure at 10–12 mmHg. Two working ports are inserted under direct vision: one under the costal margin and the other in the ipsilateral iliac fossa (Fig. 7.3). The position of this latter port (# 3), which is used for the needle holder, is crucial, as it has to be in line with the anastomosis to facilitate suturing.
5. The kidney is identified by reflecting the colon medially or through a transmesenteric window in the left side in suitable cases (Fig. 7.4).
6. Gerota's fascia is incised, and the PUJ is identified.
7. The renal pelvis is stabilized with a "hitch stitch" by passing a straight needle (3/0 or 4/0 Prolene) or a regular 5/0 Prolene in small infants passing directly through the abdominal wall and/or through a fourth 3 mm trocar (Fig. 7.5).
8. The renal pelvis is dismembered and a portion of the redundant dilated part could be excised. The ureter is spatulated, and if necessary, it can be stabilized with another "hitch stitch," similar than the pelvis.
9. The anastomosis is performed with 6/0 Monocryl® on a round body needle. The inferior part of the anastomosis is sutured first with an 8–10 cm length of suture. The remainder of anastomosis is performed with a running suture 10–12 cm long.
10. After suturing the posterior wall and starting the anterior wall, a transanastomotic stent is placed either through the fourth trocar or directly through the abdominal Wall using a 19 GA Teflon cannula. A guidewire is passed down the ureter and into the bladder. Then a double-J stent is advanced over the guidewire with vaseline oil and placed between the renal pelvis and the bladder. When this maneuver is done through a cannula, there is no possibility of using an extra instrument, which is very useful especially during learning curve.

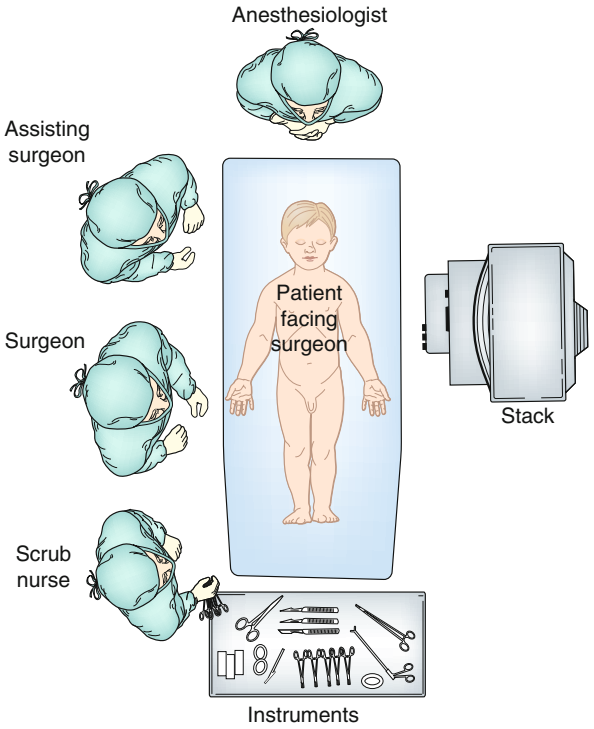

Fig. 7.1 Theater layout, personnel, and stack position for a right pyeloplasty

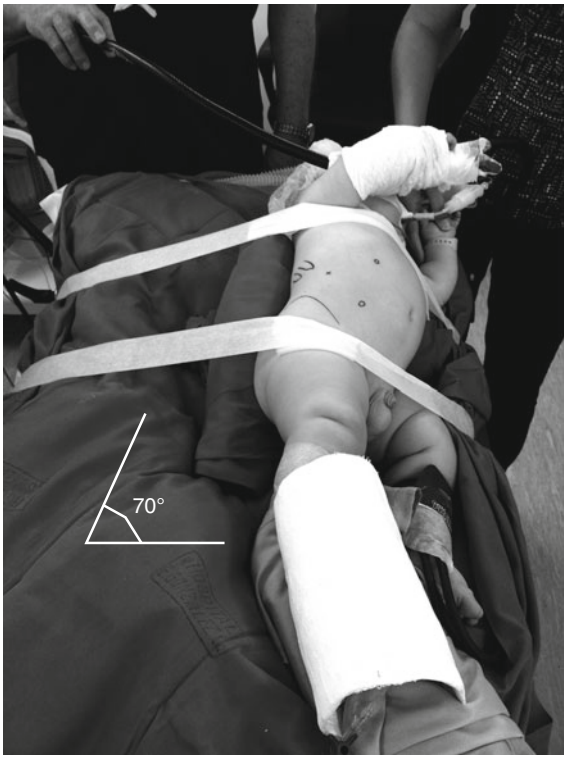

Fig. 7.2 Patient position in laparoscopic approach for left pyeloplasty

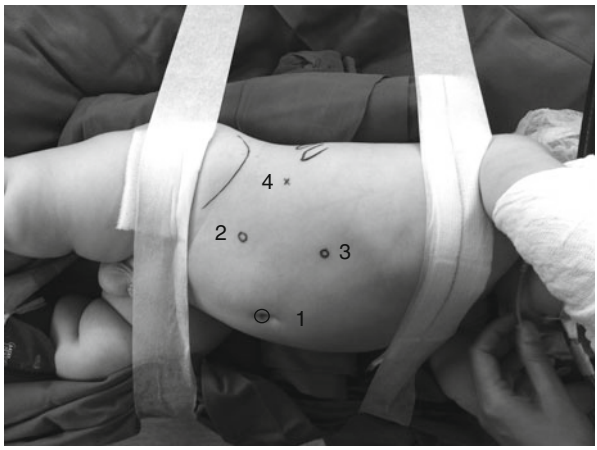

Fig. 7.3 Port positions: one in the umbilicus, one under the costal margin, and a third in the ipsilateral iliac fossa

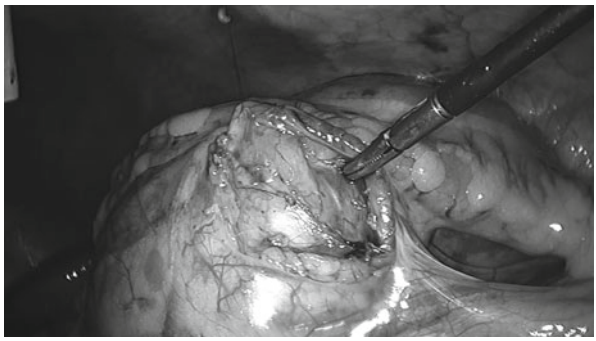

Fig. 7.4 PUJ access through a trans-mesenteric window in the left side

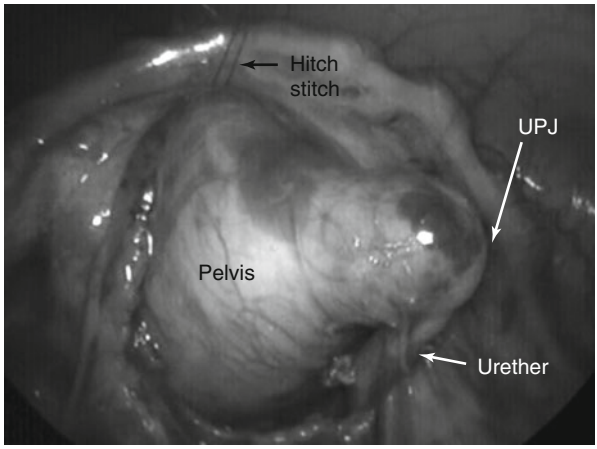

Fig. 7.5 A "hitch stitch" is use to stabilize the renal pelvis

11. The remainder of the anastomosis is completed with a further continuous suture of 6/0 Monocryl® of the same length.
12. The "hitch stitch" is removed, and the anastomosis is placed in normal anatomical position. The colon is replaced without a suture, and the mesenteric window is closed if a trans-mesenteric approach was used.
13. Ports are removed under direct vision and the incisions closed with 3/0 Vicryl to the fascia and 5/0 Monocryl or Dermabond to the skin.
14. A bladder drainage catheter is placed, either transpubically or through the urethra at the beginning or end of the surgery.
15. No peri-anastomotic drainage is used.
16. For robotic-assisted laparoscopic pyeloplasty, the operative technique is the same except that the surgeon operates the instruments remotely from the console, which provides the surgeon with a superior 3D view of the operative field. The assistant remains scrubbed and is responsible for changing the robotic instruments. A fourth trocar may be useful at the beginning in order to introduce the sutures, also managed by the assistant. The ports – which are still "big" compare with laparoscopy – are positioned in the umbilicus and under bikini line [7].
17. For a retroperitoneal approach, patient is positioned in the same manner, except that patient's back is at the edge of the operating table and patient is facing the stack. First trocar is placed in Petit's triangle with an open technique, then 5 mm trocar is placed, and dissection can be made with a homemade balloon or with the camera. Two more 5 mm trocars are placed in a triangular manner, one at the tip of 12th rib and the other one over iliac crest in the anterior axillary line, taking care of not tearing the peritoneum (Fig. 7.6). The rest of the surgical steps are almost the same as in laparoscopic approach except for the hitch stitch, which could be "down" to the psoas muscle. Extracorporeal sutures would be advisable for beginners.

Postoperative Management

Patients can be discharged the next day. Usually the child receives pain relief for 24–48 h postoperatively. Bladder drainage is withdrawn 3–5 days postoperatively. Double-J stent is removed 4–6 weeks after surgery after an USS. Patients are then reviewed 3 months later with a USS scan and thereafter in 6–9 months with an USS scan and a MAG3 study.

Complications

The overall complication rate for an Anderson-Hynes pyeloplasty is less than 5 %. The most frequent early postoperative complications are bleeding, anastomotic leak, and infection. Postsurgery stricture is the most common long-term complication, but this is rare.

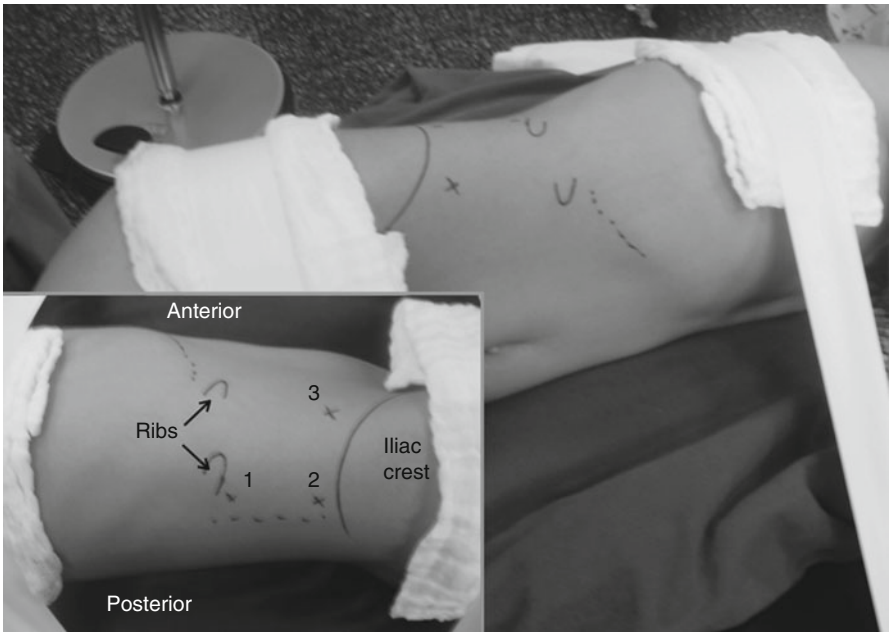

Fig. 7.6 Retroperitoneal approach, port placement

Complications as a result of the laparoscopic approach include bowel perforation, intraoperative bleeding, and the inability to complete anastomosis because of technical difficulties. In the hands of a well-trained laparoscopic surgeon, these complications should occur very infrequently.

Conclusions

There is no doubt that the Anderson-Hynes technique is the current gold standard for PUJ obstruction. Although laparoscopic pyeloplasty combines the excellent outcomes of open surgery with a shorter hospital stay and better cosmesis, it is a technically challenging surgery that is best carried out by a team of two experienced laparoscopic surgeons.

Robotic technology is already available in most of the big centers and will make MIS a possibility for even the less experienced laparoscopic surgeon. The advantages of the robotic system are the 3D view combined with the enhanced range of movements possible with the Endowrist technology. These factors greatly facilitate complex intracorporeal tasks showing similar results. The limitations are, of course, the significant setup and running costs, the lack of tactile feedback, and the significant size of the equipment, which requires a spacious theater and adequate storage space.

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Chapter 8
Robotic-Assisted Laparoscopic Pyeloplasty

Mohan S. Gundeti

Abstract The robotic platform has helped to bridge the gap between open and conventional laparoscopic surgery and has allowed the surgeons to overcome the difficulties of intricate suturing, tissue handling, and learning curve. Robotic pyeloplasty is the commonest procedure performed in the realm of robotic pediatric urology among the others like ureteric reimplantation, heminephrectomy, appendicovesicostomy, and cystoplasty. The key steps for successful completion are case selection, positioning, and port placement. Use of the UPJ as handle facilitates the anastomosis without much handling of the ureter during the anastomosis. The placement of cutaneous pyeloureteral (C-PU) stent avoids the second anesthesia for removal and does not have associated bleeding during placement, as experienced with nephroureteral stent. The outcomes are equivalent compared to open approach and have reduced morbidity. The system in its current stage is not tailored to meet the demands and requirements of pediatric application and requires further refinements and miniaturization.

Keywords Pyeloplasty • Robotic • Pediatric • Stent • UPJ

The online version of this chapter (doi:10.1007/978-1-4471-5394-8_8) contains supplementary material, which is available to authorized users.

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Introduction

Since the first description of laparoscopic pyeloplasty about two decades ago, only select surgeons were able to perform this procedure, due to complexity of suturing and time invested to master these skills [1]. The robotic platform with its inherent 7-degree freedom of movement and three-dimensional vision had bridged the gap between laparoscopic and open surgery for reconstructive procedures like pyeloplasty, with similar success. Robotic pyeloplasty is the commonest procedure performed in the realm of robotic pediatric urology among the others like ureteric reimplantation, heminephrectomy, appendicovesicostomy, and cystoplasty [2].

Preoperative Workup

The preoperative imaging is similar to open surgical approach in the form of USS scan and MAG-3 radioisotope diuretic renal scan. In the author's experience, there is no need for a retrograde pyelogram at the time of surgery except in horseshoe kidney, ectopic kidney, and redopyeloplasty. Bowel preparation is unnecessary, often a dilated colon is encountered during procedure in infants, and intraoperative insertion of a flatus tube will help to deflate the colon. MR angiogram is often useful for horseshoe kidney pyeloplasty for delineation of the aberrant renal vessels [3]. A thorough preoperative counseling with families about the procedure outcome, complications, and explaining pros and cons of the approach is mandatory.

Case Selection

In the author's experience, it is ideal to begin initially with patients older than 5 years, and as the experience builds on, then the age could be lowered (infants) and even extended to anomalous kidneys (e.g., horseshoe and ectopic) and reoperative cases. Currently the author offers this approach to all patients requiring pyeloplasty above the age of 2 months. Most important is that the operative indication should not change from an open procedure.

Approaches

Retroperitoneal approach is standard for open surgical reconstruction of renal anomalies including dismembered Anderson-Hynes pyeloplasty for UPJ. The

inherent advantage of this confined space is if there is a urine leak, it will be contained and avoids the paralytic ileus. Unfortunately due to restriction of the endoscopic movements in this confined space, it has been never popular and transperitoneal approach remains standard. To date, there is only one report of robotic pediatric pyeloplasty with retroperitoneal approach [4]. Transmesocolic approach may be feasible for a left side, while liver retraction is required for a right side pyeloplasty.

Patient Positioning

This is a key step for successful completion and preventing external pressure injuries during the surgical procedure. Diligent attention is required, especially in infants. Intraoperative orogastric tube and Foley catheter are placed to keep the stomach and bladder decompressed, facilitating the port placement.

All pressure points are well padded, and the patient is brought to the edge of the bed and positioned 30–45-° lateral decubitus position with ipsilateral side raised. The table is flexed approximately 15°, and a bean bag is placed underneath and well secured at the level of the nipple and iliac crest with silk tape. The ipsilateral arm rests comfortably on the patient's side in the natural anatomical position, whereas the contralateral arm rests outstretched supported by a bedside attachment limb support. Large foam padding is placed on the head protecting the airway and face in the case of camera approximation during operation (Fig. 8.1).

Port Placement

This is the next key step in proceeding with successful completion of the procedure. The preferred approach for initial insufflation is with the open Hasson's technique. The camera port (12 mm/8.5 mm) is first placed at umbilicus with this approach. Initial insufflation is set to 12–15 mmHg of carbon dioxide; however, this may be variable based on the age of the patient, with lower pressures (10–12) for younger patients.

Two 8 mm working ports are generally used during operation. These ports are placed after pneumoperitoneum is achieved, and under direct vision with a 30° upward-facing camera or 0° degree lens is used. The left port is placed in midline 6–8 cm superior to the umbilicus, while right port is placed about 6–8 cm away from the umbilicus in ipsilateral midclavicular line. In the author's experience, an additional 5 mm assistant port facilitates the procedure and is placed in the midline at suprapubic level (Fig. 8.1). Adequate spacing (6–8 cm) between ports and the camera is critical to prevent collision.

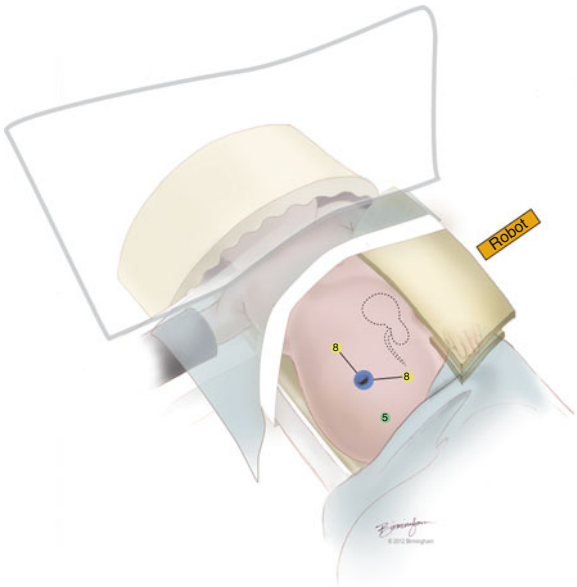

Fig. 8.1 Positioning and port placement for left robotic pyeloplasty

During port placement, special efforts are made to simulate the arm movement to avoid any inadvertent injury to the face and other body parts with articulation of the robotic arms.

Special Consideration in Infants

Because of the limited intraabdominal space, all ports are placed in the midline. Even though 5 mm robotic instruments are available, in the author's experience, these are not really helpful because the design of these instruments with the specific "gooseneck"-type joint requires greater clearance from the tissue for activation of the angle, thus making the actual functional space more limited. The pneumoperitoneum pressure is kept initially at 12 mm of Hg and then during procedure lowered to 8–10. The use of heated insufflation tubing prevents fogging during the surgical procedure. Often the space is limited, and the ports can be placed at minimum of 4–5 cm from the camera port, and this will allow completing the procedure successfully.

Port Placement in Horseshoe Kidney and Ectopic Kidney

In patients with horseshoe kidney, the ports may have to be in midline because the renal pelvis is facing anteriorly. In ectopic or pelvic kidneys, the left port and right port may have to move downwards into the pelvis because of the location of renal

pelvis. Preoperative retrograde pyelogram allows the exact location of working ports to be placed, as does a preoperative ultrasound scan.

Robot Docking (Surgical Cart): Though various positions have been described, the author prefers docking from patient's ipsilateral side, right angle to the operating table (See Fig. 8.1).

Surgical Steps

The robotic instruments preferred are left-hand precise bipolar forceps and right-hand monopolar scissors; to begin with, dissection and identification of the renal pelvis are performed first. On left side often the renal pelvis is well seen through the mesocolon, and transmesenteric approach is preferred to avoid colonic mobilization, which may otherwise be required. Once the real pelvis is identified, the dissection continues distally to mobilize the UPJ and then continued on the upper ureter. Percutaneous placement of a hitch stitch allows the renal pelvis and UPJ to be brought up into the field, for ease of transection and further reconstruction.

The renal pelvis is transected above the UPJ taking precaution not to enter the calyces, with monopolar scissor, and then the ureter is spatulated posteriorly. The spatulation should extend into the normal ureter; often use of potts scissor facilitates the spatulation, in narrow ureters. The pelvic portion of the UPJ is used as a handle during the reconstructive steps to avoid handling of the ureter. Often crossing vessels are encountered, and this needs to be transposed posterior to UPJ carefully.

The anastomosis is started at the dependent portion of the pelvis to the crouch of the spatulated ureter, in a continuous running anastomosis. Either anterior or posterior wall anastomosis is performed first, according to the anatomy and lie of the pelvis and ureter. The suture material used is 6° or 5° monofilament synthetic absorbable suture, depending on the thickness of pelvis and ureter. Creation of a watertight anastomosis with uniform tension is crucial for excellent outcomes. Following completion of anastomosis, an indwelling JJ stent is placed in antegrade fashion, or recently we have started using "C-PU" cutaneous pyeloureteral stent. This type of stent avoids a second anesthesia for removal and associated additional financial cost of the procedure. The remaining approximation of the upper part of the pelvis is completed following stent placement.

Stent Placement

Antegrade JJ: Following completion of the posterior wall of the anastomosis, through a percutaneous 14 F angiocath, a guidewire is passed and advanced into the ureter and bladder through the ureterovesical junction. The guide to confirmation into the bladder is (1) the tactile sensation as the guidewire enters into the bladder through ureterovesical junction or (2) efflux of urine from the full bladder. Over this guidewire, a stent is passed and the proximal upper coil is left in the renal pelvis.

"C-PU" Cutaneous Pyeloureteral Stent: The Salle, nephroureteral stent (Cook Medical Inc. Bloomington, IN) is prepared in way that it can be used as C-PU stent with our minimal modifications. The distal ureteral end is cut obliquely so as to traverse the anastomosis into upper ureter and not through the UV junction. The guidewire is advanced through the stent and secured externally with a small hemostat. After making skin indentation and visually inspecting the point of entry of the stent to make a straight entry into the renal pelvis, a 14 Fr angiocath is advanced under vision percutaneously into proximal renal pelvis. The preloaded stent with guidewire is advanced via the cannula of the angiocath, and the stent is directed into upper ureter through the newly reconstructed UPJ.

Once the coil is placed in the renal pelvis, the stent is stabilized, the guidewire is withdrawn, and the rest of the anastomosis is completed. The other end of the stent is secured to the skin and drained externally.

Completion of Procedure

Once the robot is undocked, the 8 and 5 mm port sites are closed under vision and then the camera port is closed. There is a high incidence of port-site hernia in pediatric population, if these are not closed properly. If an indwelling JJ stent is placed, then confirmatory plain X-ray KUB should be obtained before patient is extubated. The orogastric tube is removed and indwelling Foley catheter left for free urinary drainage 24–48 h. We do not leave a perinephric drain.

Postoperative Care

Injection of local anesthetic agent at the port site prior to placement of the ports and then after withdrawal reduces the postoperative pain. In addition, patients receive oral pain medication and intravenous morphine for breakthrough pain as required. Regular diet is resumed immediately as tolerated. Foley catheter is removed after 24 h and then C-PU stent is clamped afterwards in about 2–4 h. If there is no persistent urine leak, then the patient is discharged home on the same day. The C-PU stent is removed after a week in the outpatient clinic, in case of an indwelling JJ stent; it is removed after 4 weeks under short general anesthesia. Follow-up consists of ultrasound scan in a month and then 4, 12, and 24 months and MAG-3 radioisotope diuretics scan around 6–12 months after surgery.

Complications

These are similar to open surgical approach, in the form of anastomotic leak, stenosis, and rarely missed accessory crossing vessels especially with a retroperitoneal

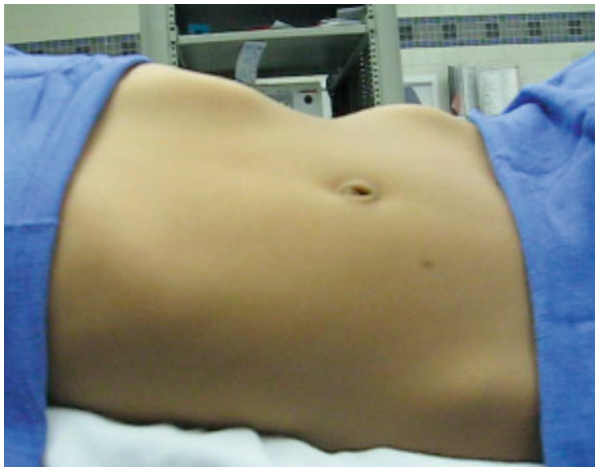

Fig. 8.2 Port-site incision

approach causing recurrent obstruction. Complications related to robotic approach are inadvertent injury to surrounding intraabdominal organs especially if the surgeon is not cognizant of the instrument movement and port insertion-related vascular injuries. The three-dimensional vision often compensates for the loss of tactile sensation, but in the beginning, it is common to exert more pressure when handling the ureter, and this may lead to ischemic injury leading to ureteral obstruction. The other causes for obstruction are malposition of the upper ureter and minor leak from newly reconstructed UPJ causing fibrosis and kinking of the ureter.

Outcomes

We have seen similar outcomes compared to open series in the form of resolution of hydronephrosis and drainage on diuretic renal scan. This has also been shown in recent literature [5].

Tips and Tricks for Successful Completion of the Procedure

1. Case Selection: Begin with first older children, and then as experience builds on (in authors opinion, about 50 cases to be performed), in younger age, e.g., infants, reoperative and anomalous kidneys UPJ should be undertaken.
2. Port Placement and Positioning: Key element for successful completion of the procedure:

   (a) Infants: To prevent dislodgement of the ports, precise skin incision for snug fitting of the port. Empty trocar is used to make a skin indentation, and then the skin incision is made across the radius of circle (Fig. 8.2).

(b) Port in Trocar Technique: Due to limited abdominal space in infants, to avoid injury to intraabdominal structure, the 8 mm working ports are directed into camera port during placement (see accompanying Video 8.1).

3. 8 mm instruments are preferred over 5 mm because of their mechanism of action and reduced functioning length required, especially in infants.
4. Diligent handling of the ureter to avoid ischemic injury.
5. Transmesenteric approach for left-sided pyeloplasty if feasible.
6. Hitch stitch on the proximal pelvis for exposure and delineation of the UPJ.
7. The use of "C-PU" stent to avoid second anesthesia and reduce financial burden without compromising the outcomes.
8. Team work especially the OR staff be similar for at least initial 20 cases. Debriefing after each case and positive reinforcement.
9. Keeping all sutures required and accessories ready in OR prior to start of the procedure to avoid delay.
10. Pyeloplasty in horseshoe and ectopic kidneys; be aware of the aberrant renal vessels mimicking the ureter.

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Chapter 9
Transposition of Lower Pole Vessels: "The Vascular Hitch"

Prasad P. Godbole

Abstract The traditional surgical technique for pelviureteric junction obstruction (PUJO) is the dismembered pyeloplasty which may be performed open, laparoscopic, or robotic assisted. In a select group of patients, aberrant lower pole crossing vessels may be responsible for an extrinsic compression of the pelviureteric junction. Relocation of the lower pole vessels can relieve the obstruction in such cases. This chapter focuses on the indications, contraindications, technical aspects, and postoperative management of the laparoscopic relocation of the lower pole vessels also known as the vascular hitch or pyelopexy.

Keywords Pelviureteric junction obstruction • Laparoscopy • Pyeloplasty • Lower pole vessels

Introduction

Laparoscopic transposition of the lower pole vessels is suitable in children in whom there is a high index of suspicion of lower pole vessels. Transposition of lower pole vessels was first described by Hellstrom in 1951 [1]. Suspicion of lower pole vessels is based on a normal antenatal history, intermittent episodes of flank pain with a predominantly extrarenal pelvic dilatation on ultrasound, worse during the time of the pain. Children tend to be older and in between episodes may even have a normal renal ultrasound with minimally dilated renal pelvis. Furosemide administration during an isotope renogram may precipitate the pain, and the renogram demonstrates an obstructive pattern with minimal washout with furosemide.

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Indications for the Vascular Hitch

If as described above, there is a high index of suspicion of lower pole vessels, a vascular hitch may be considered. However, the surgeon must be prepared to perform a laparoscopic dismembered pyeloplasty if there are no lower pole vessels or if the vessels do not appear to be the causative factor of the PUJO. In a retrospective review of eight children undergoing the vascular hitch, three anatomical variations of the lower pole vessels were recognized: vessels in front of the pelvis, in front of the PUJ, and below the PUJ causing ureteric kinking [2]. The authors recommend performing the hitch for vessels below the PUJ.

Preoperative Investigations

As for PUJ obstruction, the preoperative investigations consist of:

1. Renal ultrasound: with increasing resolution of the ultrasound scanners and experience of pediatric radiologists, lower pole vessels may be visualized on Doppler ultrasound.
2. MAG 3 renogram.

All imaging *MUST* be available and on the screen in the OR at the time of the surgery.

All children should have a baseline renal biochemistry and full blood count. The author does not routinely group and save serum for this procedure or a laparoscopic pyeloplasty.

Instrumentation

- Standard 5 mm laparoscopic set to include Kelly forceps, atraumatic graspers, scissors, diathermy hook, and needle holder.
- The author prefers to have available bipolar diathermy forceps if required.

Anesthesia

General anesthesia with endotracheal intubation and full muscle relaxation

Patient Position

The patient is placed in a renal position with a sandbag under the lower costal margin to elevate the affected side. The patient should be well supported posteriorly.

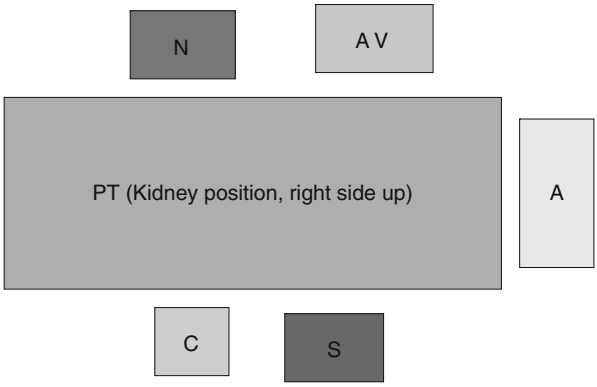

Fig. 9.1 Position of the patient (*P*), surgeon (*S*), camera holder (*C*), audiovisual equipment (*AV*), scrub nurse (*N*), and anesthetist (*A*) for transposition of right renal vessels

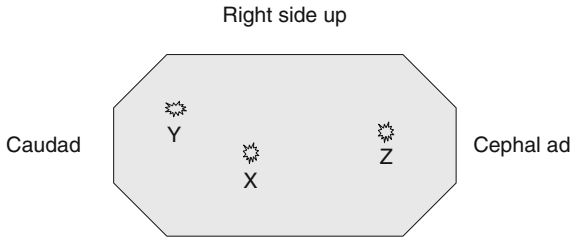

Fig. 9.2 Port position *X* (primary) and *Y-Z* (secondary ports)

Anteriorly the patient is supported in the region of the chest but not in the region of the trunk as this can interfere with the working ports and instruments. The patient should be stabilized with broad tape over the pelvis and thorax. The position of the patient, surgeon, anesthetist, and equipment is shown in Fig. 9.1.

Port Position

One primary umbilical port and two working ports are required. The port positions are shown in Fig. 9.2. A trick to facilitate umbilical primary port access by the open technique is to tilt the table away from the surgeon to make the patient more supine. Once access is obtained, the table can be returned to its original position and the patient in the renal position.

Operative Technique

- The ascending or descending colon is reflected medially to expose the perirenal fascia and quite often the bulging renal pelvis.
- The perirenal fascia is incised and reflected medially and the adventitia over the pelvis cleared.
- The pelvis is traced inferiorly to the PUJ, or the ureter is traced superiorly to expose the lower pole vessels (Fig. 9.3).

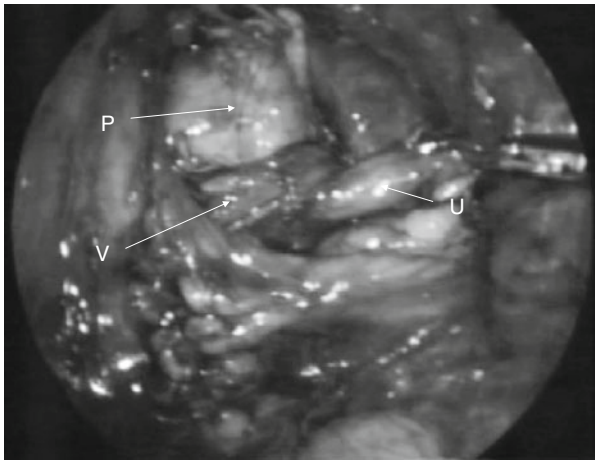

Fig. 9.3 Renal pelvis (*P*), ureter (*U*), and vessels (*V*) exposed (Reprinted from Godbole et al. [3]. Copyright© 2006, with permission from Elsevier)

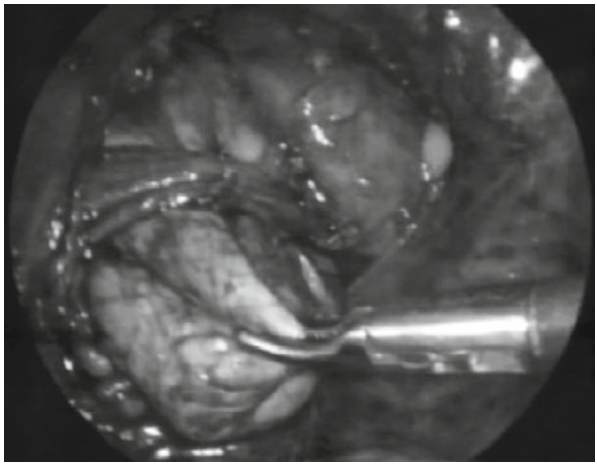

Fig. 9.4 Renal pelvis (P) fully mobilized (Reprinted from Godbole et al. [3]. Copyright© 2006, with permission from Elsevier)

- If lower pole vessels are identified, with a combination of scissors/bipolar hook, the pelvis and ureter are fully mobilized so that they are completely free from the lower pole vessels (Fig. 9.4). This can be demonstrated by the "shoe shine" maneuver as seen in the accompanying video.
- A useful trick is to divide the fibrous strands towards the hilar end of the lower pole vessels to increase their mobility. A further tip to check the adequacy of dissection is to transpose the vessels superiorly over the pelvis where they should sit in a comfortable position on release of the pelvis.
- Inspection of the PUJ and proximal ureter is now made and any kinks straightened out. If there are no vessels or they do not appear to be contributing to the obstruction, either a laparoscopic or open pyeloplasty can be performed depending on surgeon's preference.

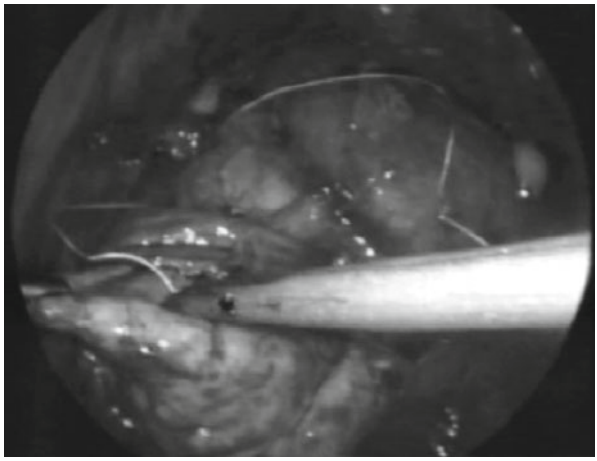

Fig. 9.5 Vessels pexed superiorly (Reprinted from Godbole et al. [3]. Copyright © 2006, with permission from Elsevier)

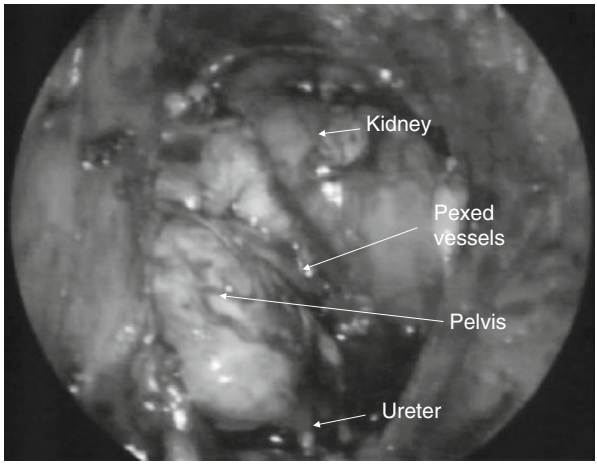

Fig. 9.6 Appearances at the end of the procedure (Reprinted from Godbole et al. [3]. Copyright© 2006, with permission from Elsevier)

- The vessels are fixed in position by suturing the renal pelvis on either side of the vessels with 2–3 absorbable 4.0 or 5.0 Vicryl sutures (Fig. 9.5) No drains or stents are required. The final appearance of the pexed vessels is seen in Fig. 9.6.

Postoperative Care

The patient is allowed to eat and drink as tolerated soon after the procedure and is discharged when mobilizing usually the next day. The author routinely performs a US and MAG 3 renogram 6 weeks postoperatively.

Outcomes

Early and intermediate follow-up of an initial cohort of patients where this technique was performed has demonstrated a success rate of over 95 % [3, 4]. One patient of that cohort had recurrent pain needing a laparoscopic dismembered pyeloplasty. Other series demonstrate similar results [4].

Conclusion

The vascular hitch is a useful alternative to dismembered pyeloplasty in carefully selected cases where lower pole vessels are deemed to be the sole etiology. The procedure is simple to perform and relatively quick with a good success rate. Previous vascular hitch surgery does not seem to preclude a further open/laparoscopic pyeloplasty for recurrent PUJO [3, 5].

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Chapter 10
Minimally Invasive Ureteroureterostomy

Matthew D. Timberlake and Sean T. Corbett

Abstract Technological advances have not only enhanced our ability to detect urological disease but also resulted in dramatic changes/advancements in the tools available to treat them. Up until recently, laparoscopic techniques in pediatric urology had been confined mainly to academic centers given the challenges associated in learning the techniques or the high learning curve. However, the addition of the robot to our surgical armamentarium has dramatically expanded the role of minimally invasive surgery as well as its breadth of use. Pioneers continue to develop and push the boundaries as innovations evolve. The scope of procedures performed is now ever expanding, and it includes complex ureteral surgery. Previously, the delicate nature of intracorporeal suturing and the fine tissue handling required limited the applicability of laparoscopic techniques of this sort to very few expert laparoscopists. The robotic systems, however, have facilitated a shortened learning curve in addition to improved precision and performance. As these changes have occurred, surgeons have begun to tackle more challenging problems including the ureteroureterostomy. The general concept of repair remains the same: restore the normal flow of urine. In this chapter, the author describes in detail his approach to an obstructed superior moiety ureter of a duplex system associated with a normal inferior moiety ureter and collecting system. The author has performed these both laparoscopically and robotically, but his preference now is to use the robot. A detailed description of his preoperative, intraoperative, and postoperative management follows.

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Background

Antenatal hydronephrosis is detected in 1–5 % of all pregnancies and is one of the most common congenital anomalies detected on prenatal ultrasound [1]; often it is associated with vesicoureteral reflux or ureteropelvic junction obstruction. However, it may also be associated with a duplicated collecting system especially where the anomaly of complete ureteral duplication occurs. In this circumstance the superior moiety renal unit is often associated with a dilated ureter secondary to a distal obstruction, commonly a ureterocele or ectopic insertion. Conversely, the inferior moiety renal unit is often associated with vesicoureteral reflux. The phenomenon above is described by the Weigert-Meyer rule. Several clinical scenarios may develop in the above setting, but for the purposes of this chapter, the focus will be on a functional superior moiety renal unit associated with a distal obstruction (ureterocele or ectopic insertion) and a non-obstructed and non-refluxing ipsilateral inferior moiety renal unit. One management option, originally described by Foley in 1928 with renewed interest in the procedure after it was revived in 1965 by Buchtel, is ureteroureterostomy (U-U) [2, 3]. Other disease etiologies that may necessitate U-U include congenital midureteral stricture, iatrogenic stricture disease, and ureteral polyps. These conditions differ from the duplicated systems, however, in that the U-U is performed in an end-to-end fashion for a single ureter versus an end-to-side fashion for the duplicated ureters. Previously concerns were raised about the potential risks associated with the U-U procedure principally that it could jeopardize the function and drainage of the non-obstructed or non-refluxing ipsilateral renal moiety. However, this has not proven to be the case [4–8]. The open surgical technique has varied little from its original descriptions by Foley and Buchtel, although some have made modifications but mostly in the surgical approach [4–6, 9].

In the late 1970s, laparoscopic surgery was introduced to pediatric urology as a tool to evaluate for non-palpable testes [10]. Since then, conventional laparoscopic approaches have been utilized for numerous pediatric urological surgeries including U-U [11, 12]. Technological innovations have enhanced the armamentarium for the management of urological disease, and various minimally invasive options now exist including laparoscopic approaches via single or multiple trocars and robotic-assisted laparoscopic approaches. Although Nezhat performed the first ureteroureterostomy laparoscopically in 1992, Bhandarkar et al. in 2005 reported on the first laparoscopic ureteroureterostomy in a 16-year-old with a midureteral stricture [13]. Since then, there have been many more case series reporting successful U-U procedures, many of which utilized the da Vinci® robotic system (Intuitive Surgical, Sunnyvale CA 94086, USA) to assist [14–19]. Although the laparoscopic approach is feasible, the delicate intracorporeal suturing and fine reconstructive techniques necessary for

the repair with current conventional laparoscopic instruments remain challenging outside the hands of expert laparoscopic surgeons. The robotic systems have improved precision, efficiency, and performance and thus a more rapid climb up the learning curve, thus broadening the applicability of the minimally invasive U-U.

Embryology and Anatomy

The reciprocal induction of the metanephric mesenchyme and the ureteral bud is responsible for normal renal and ureteral development. The proper differentiation of these primordial structures is essential for normal development, and any deviation in the normal pathway of embryological development can result in abnormalities. Duplex collecting systems are one of the more common abnormalities detected in the upper urinary tract. Duplex kidneys result from the induction events of two separate ureteral buds with the metanephric mesenchyme. Associated with the duplex renal units and collecting systems, one may encounter a bifid pelvis and various levels of ureteral duplication depending on the level at which the ureters join. In most cases duplication anomalies are asymptomatic. Those that are detected often are in relation to vesicoureteral reflux or obstruction.

Refinements in prenatal ultrasound have improved our ability to detect fetal anomalies in utero. Antenatal hydronephrosis is one of the most common abnormalities detected with prenatal ultrasound. Complicated renal duplication anomalies can often be found associated with fetal urinary tract dilations. In the case of complete ureteral duplication anomalies, the final position of the ureteral orifices in the bladder is counterintuitive as described previously in the Weigert-Meyer rule; the superior moiety is most often associated with obstruction secondary to a ureterocele or an ectopic insertion, and the inferior moiety is commonly associated with vesicoureteral reflux (Fig. 10.1).

Routine postnatal evaluation of duplication anomalies should include renal ultrasound (RUSD) and voiding cystourethrogram (VCUG) studies. RUSD can diagnose duplex kidneys, hydronephrosis, dilated ureters, and a ureterocele. Voiding cystourethrography can be used to detect vesicoureteral reflux and better characterize the ureterocele. In many renal duplication cases, the superior moiety is frequently dysplastic and is thus a small contributor to overall renal function. Nuclear renal scans are used to determine the differential function between the superior and inferior moieties. In the case of a poorly or nonfunctioning superior moiety, an extirpative procedure/partial nephrectomy with ureterectomy may be considered. However, where surgery is required but both the superior and inferior moieties contribute substantially to normal renal function, every effort should be made to preserve renal function to both moieties. For the purposes of this chapter, the author will focus on the scenario with a duplex system including complete duplication of the ureters and normal renal function to both the superior and inferior moieties

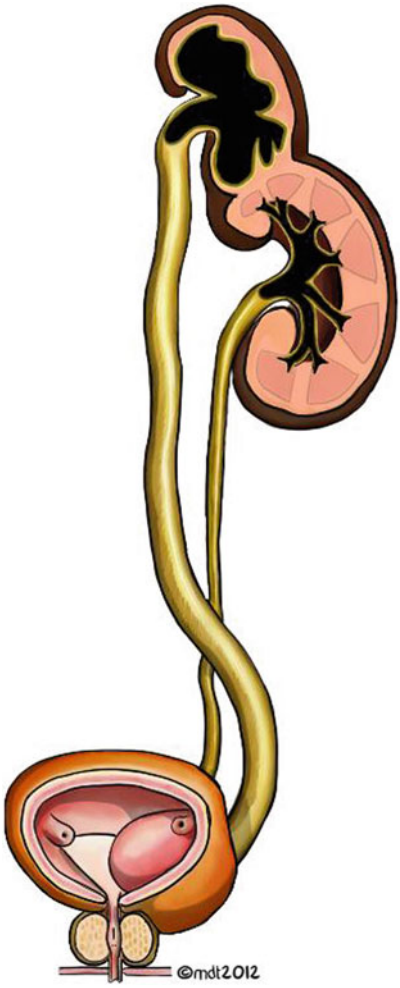

Fig. 10.1 Duplicated left collecting system; complete left ureteral duplication with obstructed superior moiety ureter (Courtesy of Matthew Timberlake)

but with a distal obstruction (ureterocele or ectopic insertion) associated with the superior moiety and a non-refluxing inferior moiety.

Indications

1. Ureteral stricture disease (e.g., iatrogenic, polyps, congenital)
2. Complete ureteral duplication
   (a) Obstructed superior (or inferior) moiety with non-obstructed and non-refluxing inferior (or superior) moiety
   (b) Inferior moiety with high-grade vesicoureteral reflux and non-obstructed and non-refluxing superior moiety

Contraindications

1. Complete ureteral duplication with obstruction and/or reflux of both ureters

Preoperative Preparation: In addition to imaging and urine studies, all patients are given a diet of 24 h of clear or low-residue liquids depending on patient age to help reduce the bulk of stool in the colon. Patients are also given a suppository the night before.

Specific Instrumentation: The case description that follows is that of a robotic-assisted laparoscopic (RAL) U-U (see accompanying Video 10.1), which this author prefers; however, similar instrumentation and room setup can be used for a pure laparoscopic approach.

1. Equipment
   (a) Infant or pediatric cystoscopy equipment
      (i) Appropriately sized ureteral catheters, double-J ureteral stents, and guide wires
   (b) da Vinci® robotic system
   (c) Robotic ports
      (i) 8.5 mm or 12 mm camera cannula
      (ii) 2×5 mm or 8 mm cannulae
   (d) Robotic instruments
      (i) 5 mm
         1. Hook cautery
         2. Grasper (preferably Maryland type)
         3. Fine-tip needle driver
         4. Curved and round-tip scissors
      (ii) 8 mm
         1. Same as above
         2. Curved "hot" scissors
   (e) Conventional laparoscopic instruments
      (i) Needle driver
      (ii) Grasper
      (iii) Irrigation/aspiration device
2. Room and patient setup (Fig. 10.2)
   (a) Patient position – supine and secured to table to allow for table rotation and tilting prior to robot docking
   (b) Robot position – modified-side-, side-, or end-dock near the foot of the table depending on robot model and size of patient

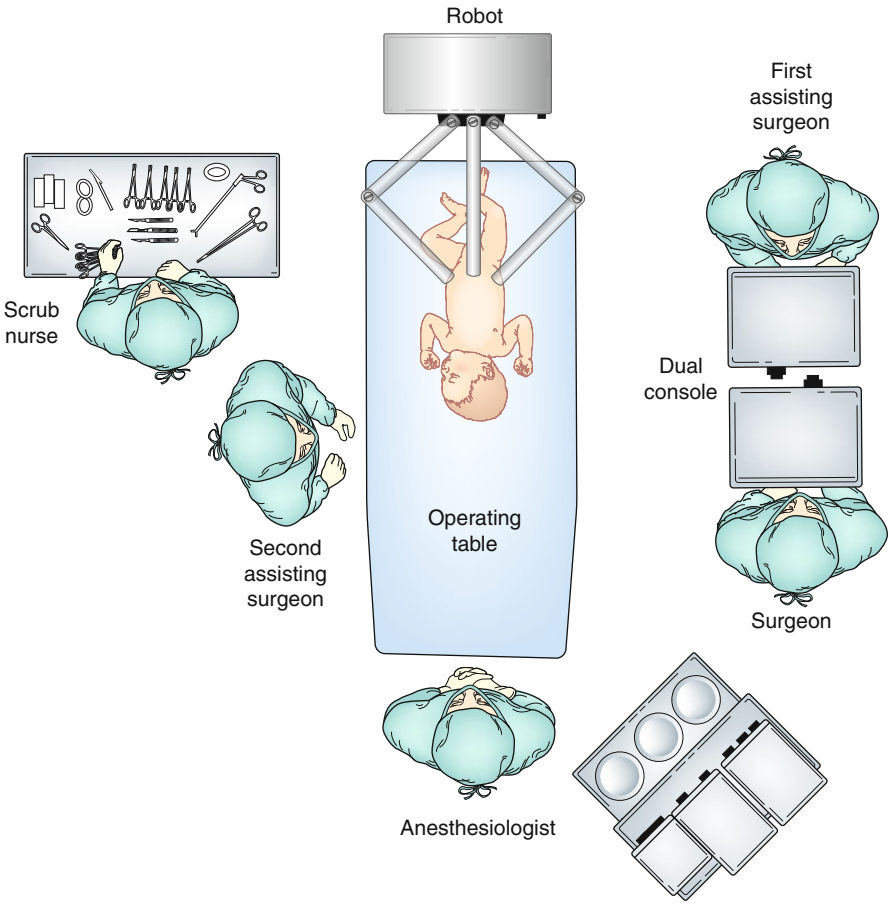

Fig. 10.2 Room setup for RAL ureteral surgery

Operative Technique

1. Cystoscopy and retrograde imaging is performed with the patient in lithotomy position. A ureteral catheter is advanced into the recipient (ipsilateral non-obstructed) ureter; stent size can be determined at this time. Once this is completed, the ureteral catheter is then secured to a latex-free bladder catheter with a silk suture.
2. Following catheter placement, the patient is repositioned supine and slightly frog-legged at foot of the table with all pressure points padded and then secured in position (Fig. 10.3). The patient is prepped and draped in a standard surgical fashion with the ureteral and bladder catheters included in the prep.
3. An 8.5 mm (or 12 mm, depending on size of the child) trocar is then placed through the umbilicus in a modified Hasson fashion. A 3–0 polydioxanone suture is placed through the fascia to help hold the trocar in place during surgery and to facilitate wound closure at the end of the procedure. The abdomen is then

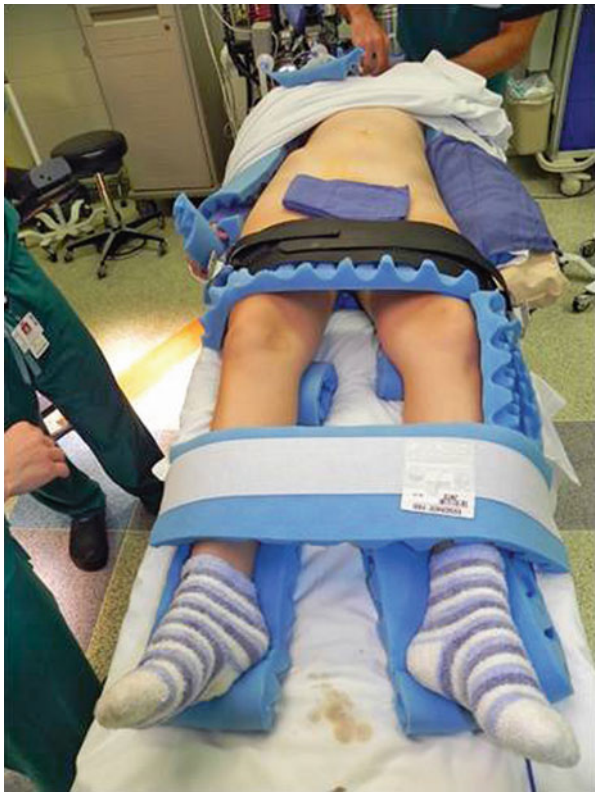

Fig. 10.3 Patient positioning and padding for RAL ureteral surgery (Courtesy of Patricio Gargollo)

insufflated. Two 5 mm trocars are then placed under direct laparoscopic vision in the midclavicular line on both sides and 2–3 cm below the umbilicus. These two trocars can be moved more cephalad depending on the age of the infant/child to provide more room to operate intracorporeally (Fig. 10.4).

3–0 polydioxanone suture is again pre-placed through the fascia to facilitate wound closure at the end of the procedure. The table is then placed in 10–15° Trendelenburg position and rotated slightly so that the operative side is elevated (Fig. 10.5). The robot is then docked (Fig. 10.6).

4. The ureters are approached in a transperitoneal fashion. A robotic grasper (Maryland preferred) and hook cautery are utilized through the 5 mm ports. The ureters are easily identified through the peritoneum and exposed by incising the peritoneum where the ureters cross the iliac vessels. The ureters are mobilized proximally and distally for approximately 2–3 cm in either direction using blunt dissection and electrocautery. Care is taken to avoid devascularization of either ureter. The ureteral catheter is visualized in the recipient ureter which is mobilized free from the donor (ipsilateral obstructed) ureter just caudal to the level of the iliac vessels. The hook cautery is then replaced with robotic curved scissors. The dilated ureter is then divided. If obstructed and refluxing, then the distal end of the divided donor ureter is ligated using polyglactin suture; otherwise, the distal end can be left alone.

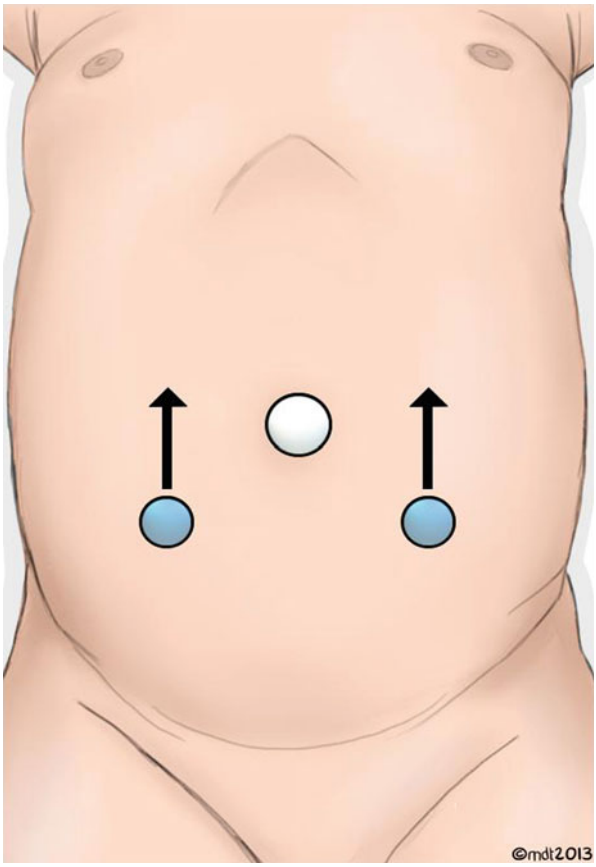

Fig. 10.4 Trocar positioning for RAL ureteral surgery. Lateral trocars can be adjusted cephalad depending on size of patient per arrows (Courtesy of Matthew Timberlake)

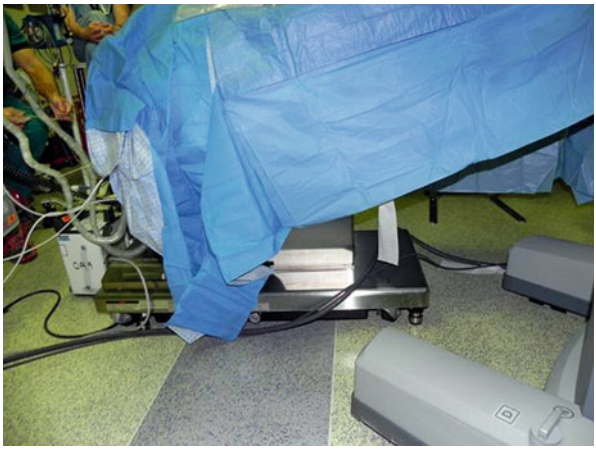

Fig. 10.5 Operative table rotated and placed in Trendelenburg position (Courtesy of Patricio Gargollo)

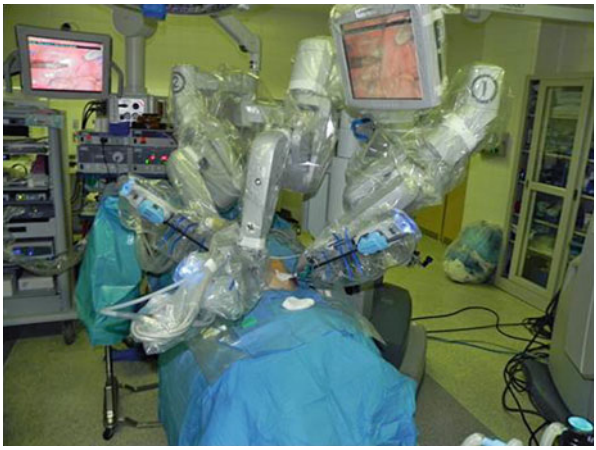

Fig. 10.6 da Vinci® modified side-dock position for RAL ureteral surgery (Courtesy of Patricio Gargollo)

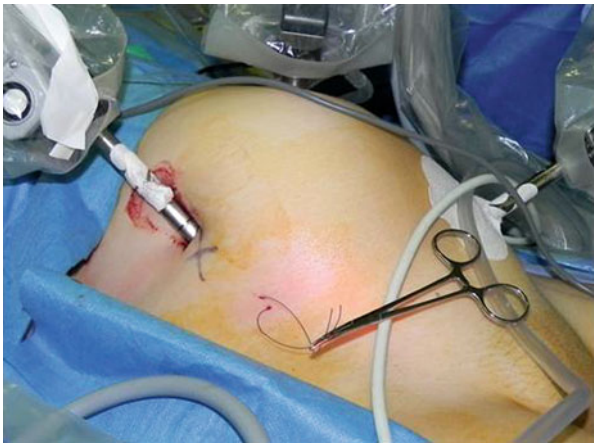

Fig. 10.7 Hitch stitch in clamp (Courtesy of Patricio Gargollo)

5. At this point, the curved scissors are replaced by a robotic needle driver, and the author places a 2–0 or 3–0 polydioxanone suture on an SH needle (straightened for larger children) percutaneously through the low abdomen in the midclavicular line as a hitch stitch to gently elevate the recipient ureter in preparation for the anastomosis. Tension can be adjusted by clamping the suture outside the body (Fig. 10.7).
6. The needle driver is replaced with a round-tip scissors, and the ureterotomy is performed in the recipient ureter anteromedially in preparation for an end to side (donor to recipient ureter, respectively). The ureteral catheter is readily observed. If the donor ureter requires spatulation, this should also be performed at this time (round-tip scissors preferred).
7. Next, the first/lateral side of the tension-free watertight anastomosis is performed in a simple running and locking fashion using synthetic monofilament poliglecaprone suture (size adjusted depending on age of patient).

8. After completion of the lateral anastomosis, a guide wire is advanced by the 2nd assistant surgeon through the open-ended ureteral catheter to the level of the ureterotomy. The wire is manipulated by the robotic Maryland and needle driver into the proximal end of the donor ureter and advanced proximally. The ureteral catheter is then removed, and an appropriately sized stent is advanced over the guide wire into the collecting system of the donor ureter, thus bridging the anastomosis between the two ureters. In appropriate patients, a string can be left on the distal end of the stent to facilitate removal postoperatively and avoid a second anesthetic. Some surgeons advocate leaving a stent in the recipient ureter only; however, this raises the question of whether a stent need be placed at all.
9. The medial portion of the anastomosis is then completed with a second synthetic monofilament poliglecaprone suture in the same fashion as the lateral anastomosis. The hitch stitch is then cut and the ureter returned to its normal anatomic position. The abdomen is carefully inspected for hemostasis, and any fluid accumulated during the procedure can be evacuated with a suction-irrigator device.
10. Finally the robot is undocked. The trocars are removed and the pre-placed fascial stitches are tied down to close the incisions. Synthetic monofilament poliglecaprone suture is then used to close the skin incisions. 0.25 % bupivacaine is then injected into the incision sites for postoperative analgesia. Skin adhesive is applied for dressing. A KUB image can be performed to confirm appropriate ureteral stent position if there are concerns. If adjustments are required, the bladder catheter is removed, the patient repositioned, and repeat cystoscopy and stent positioning performed. The bladder catheter is then replaced.

Postoperative Management

Patients are started on fluids and diet on admission to the inpatient wards. Ketorolac is used for postoperative pain control and supplemented with narcotics as needed. The bladder catheter is removed on postoperative day one, and the patient is discharged later that same day.

It is this author's preference to maintain these patients on prophylactic antimicrobials (most commonly trimethoprim-sulfamethoxazole 2 mg/kg/day, cephalexin 10 mg/kg/day, or nitrofurantoin 2 mg/kg/day) while the stent remains indwelling. Patients return to clinic for stent removal in 2 weeks if the string was left in place after surgery or in approximately 4–6 weeks for cystoscopy and stent removal under anesthesia if the string on the stent was removed in the operating room during the initial procedure.

Repeat renal ultrasound imaging is performed 6–8 weeks after stent removal. Additional follow-up is arranged accordingly.

Complications

Although there have been a growing number of laparoscopic and robotic-assisted laparoscopic ureteroureterostomy procedures performed, the overall clinical experience remains limited.

The complications reported in the literature thus far are rare, but this is difficult to quantify, as published data is limited [18–21]. The operative techniques and lessons learned from laparoscopic and robotic-assisted laparoscopic pyeloplasty have facilitated the evolution of this approach, but as with any surgery, the surgeon must be aware that there are many potential opportunities for complications to occur: with anesthesia or positioning, during port placement, during the procedure, during port closure, and postoperatively.

For the sake of this discussion, the focus will be on those specifically related to ureteroureterostomy for any indication. These are similar to those observed in minimally invasive pyeloplasty and include urine leak/extravasation, persistent hydronephrosis, and ureteral stricture.

Urinary extravasation is best managed proactively with stent placement. As described above, irrespective of the approach (laparoscopic or robotic), this author places the stent across the anastomosis into the donor ureter to limit the resistance to urine flow through the anastomosis. Although some have suggested leaving the stent in the recipient ureter, theoretically this may increase resistance to the flow of urine across the anastomosis and theoretically may result in an increased risk of urinary leakage. One could argue that no stent may be more appropriate if one believes this theory; however, there have been no reports of urinary extravasation in the literature associated with laparoscopic or RAL U-U. Any urinary extravasation will collect in the peritoneal cavity as urinary ascites. In the pediatric population, especially in infants and young children, abdominal distention and ileus may be the only indication that there is an underlying leak, especially if no drain was placed.

In the case of ureteral stricture, this is likely to result if there is undue tension on the anastomosis (unusual in the pediatric population due to the redundancy of the obstructed ureter) or aggressive ureterolysis which both may lead to ischemia. In order to assure a tension-free anastomosis and minimize the risk of ischemia, the surgeon should adequately, but cautiously, mobilize the ureter(s) proximally and distally to the level of anastomosis.

Finally, persistent hydronephrosis can be a challenge postoperatively as it might be difficult to know when and if further intervention is required. Often in this patient population, the proximal hydronephrosis is chronic and it resolves minimally and at times not at all in some patients; the system remains dilated even if non-obstructed. As with all surgeries, the surgeon must have an informed discussion about the risks of surgery with the patient and family prior to proceeding. Even though the published rates of complications for these procedures are low, any unusual symptoms/signs should prompt further evaluation.

Author's Experience

Over a 4-year period, this author has performed 6 RAL U-U procedures. There has been a wide variation in the patient demographics and perioperative characteristics which are listed in Table 10.1. Operative times have been widely variable depending on disease characteristics as well as timing of procedure in terms of the author's

Table 10.1 Author's experience with RAL U-U: patient demographics and perioperative characteristics

Patient	Age (years)	Gender	Presentation	Side	Diagnosis	Operative time (min)	Length of hospital stay	Complications	Outcome
1	8	M	Abdominal pain	Right	Retrocaval ureter	286	1.5	None	Pain resolved
2	17	M	Renal colic	Left	Miduretral stricture	303	1.5	None	Pain resolved
3	2	F	Prenatal hydronephrosis	Right	Duplex: superior moiety ureterocele	265	1	None	Resolved hydronephrossis
4	6	M	Abdominal pain	Left	Midureteral stricture-polyps	183	1	None	Pain resolved
5	6	M	Abdominal pain	Left	Proximal ureteral stricture-polyps	159	1	None	Pain resolved
6	5	F	Incontinence	Left	Duplex: superior moiety ectopic ureter	297	1	None	Resolved incontinence

learning curve with robotic surgery. All operative times include cystoscopy and stent placement. The author's success rates and outcomes for RAL U-U procedures have been very good without complications over 1–3 years of follow-up thus far and resolution of symptoms and/or hydronephrosis. These results mimic those of other series reported in the literature [12, 14, 16, 17, 22]. At our institution this is the preferred approach.

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Chapter 11
Laparoscopic Adrenalectomy

Imran Mushtaq and Francisca Yankovic

Abstract Laparoscopic adrenalectomy is considered to be the standard of care for the surgical excision of the adrenal gland. Transperitoneal and retroperitoneoscopic approaches are the two principal laparoscopic routes to the adrenal gland. Both are safe and effective as open adrenalectomy, but offer the benefits of decreased blood loss, less postoperative pain, shorter hospital stay, rapid convalescence, and improved cosmetic outcome. This technique can safely be used in patients with pheochromocytoma, adrenal adenoma, adrenal adenocarcinoma, Cushing's syndrome, neuroblastoma, and incidentaloma. Relative contraindications include previous surgery of the liver or kidney, large tumors (>8–10 cm in diameter), or coagulation disorders.

Although the transperitoneal route is used more widely, the retroperitoneal approach provides a more direct exposure of the adrenal gland and a better visualization of the adrenal vein. It avoids also colonic mobilization, minimizes the risk of injury to hollow viscera, and the potential risk of adhesion formation. However, the reversed orientation of the kidney and hilum, combined with a significantly smaller working space, may make this approach difficult to master. Familiarity with this approach for renal surgery has made this the preferred approach for adrenal surgery in our institution.

Keywords Laparoscopic adrenalectomy • Retroperitoneoscopic adrenalectomy • Pediatric adrenalectomy • Minimally invasive surgery • Adrenal masses

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Introduction

Laparoscopic adrenalectomy is considered the standard of care for the surgical excision of the adrenal gland. Recent guidelines published in 2010 by the International Pediatric Endosurgery Group (IPEG) have validated the minimally invasive treatment for adrenal masses in children [1].

Since the initial report of laparoscopic adrenalectomy in 1992 [2], it has evolved into a feasible and reproducible minimally invasive procedure for benign adrenal tumors [3]. Treatment of suspected malignant lesions such as adrenocortical carcinoma is recommended only for experienced surgeons and localized tumors less than 6 cm in diameter [4].

Transperitoneal and retroperitoneal approaches are the two principal laparoscopic routes to the adrenal gland [5, 6]. Both approaches are safe and effective as open adrenalectomy, but offer the additional benefits of decreased blood loss, less postoperative pain, shorter hospital stay, rapid convalescence, and improved cosmetic outcome [7]. Whether the laparoscopic approach confers benefit in terms of greater hemodynamic stability in patients with catecholamine excess is undefined. There is a paucity of literature in the available in pediatric population, but the number of case series reported in the last 5 years has increased substantially.

Although the transperitoneal route is used more widely, the retroperitoneal approach offers distinct advantages that make it a valuable alternative route to the adrenal gland. It avoids colonic mobilization, minimizes the risk of injury to hollow viscera, and the potential risk of adhesion formation. The exposure of the adrenal gland is direct, and the visualization of the adrenal vein is more precise. These observations have been made by Waltz in an experience of more than 500 prone retroperitoneal adrenalectomies [8]. With the patient in a prone position, the reversed orientation of the kidney and hilum, combined with a significantly smaller working space, may make this approach difficult to master. Familiarity with this approach for renal surgery has made this the preferred approach for adrenal surgery in our institution.

Anatomy

Left Adrenal Gland

The left adrenal gland is smaller than the right and lies in the renal fossa at the medial aspect of the upper pole of the left kidney. The arterial supply is derived from the left superior (left inferior phrenic artery), middle (aorta), and inferior (left renal artery) adrenal arteries. The main left adrenal vein joins with the left inferior phrenic vein to drain into the left renal vein.

Right Adrenal Gland

The right adrenal gland is larger than the left and is of variable shape. It is located at the medial aspect of the upper pole of the right kidney, behind the vena cava in a very deep and high position. The arterial supply derives from the right superior (inferior phrenic artery), middle (aorta), and inferior (right renal artery) adrenal arteries. The main right adrenal vein drains into the posterior lateral aspect of the vena cava after a short horizontal course. Approximately 10 % of individuals have an accessory adrenal vein, which drains into the right hepatic vein.

Indications

1. Pheochromocytoma
2. Adrenal adenoma
3. ACTH-dependant Cushing's syndrome
4. Neuroblastoma (<8 cm without involvement of adjacent organs)
5. Adrenocortical tumor (<8 cm without involvement of adjacent organs)
6. Incidentaloma

Relative Contraindications

1. Previous surgery of the liver or kidney
2. Large tumors (>8–10 cm in diameter)
3. Coagulation disorders

Preoperative Work-Up

Imaging

A detailed ultrasound of the kidneys and adrenal glands is an essential investigation in all children suspected of having an adrenal lesion. The ultrasound provides information regarding the presence of a distinct lesion, including its size and whether it is cystic or solid. In some cases, there will be bilateral diffuse enlargement of the adrenal glands without a focal lesion, such as in central Cushing's syndrome. It is also essential to determine if there is intravascular extension of a lesion into the

adrenal vein and inferior vena cava. This information will serve as a guide to the suitability of the laparoscopic approach and also for deciding the technique for specimen removal. The information gained from an ultrasound must be supplemented with a CT scan and/or an MRI scan.

Blood Tests

All patients should have routine blood test, which should include serum creatinine, hemoglobin level, and a group/save of serum. Clotting parameters do not need to be checked routinely, unless there is a history of bleeding disorders.

Pheochromocytoma

Hypertensive patients with a pheochromocytoma secrete excessive quantities of catecholamines, and the measurement of urinary catecholamines is diagnostic in 95 % of patients. Preoperative preparation in such cases requires the administration of phenoxybenzamine for 7 days prior to surgery. In addition, the administration of beta-blockers (propranolol) can decrease the risk of tachyarrhythmias, but should not be given without prior alpha-blockade. These patients require a multidisciplinary team comprising a nephrologist, endocrinologist, and anesthetist to prepare and stabilize the patient for surgery.

Antibiotics

All children receive a single dose of an appropriate intravenous antibiotic, either prior to leaving the ward or at the induction of anesthesia. The authors prefer an aminoglycoside such as amikacin or gentamicin.

Specific Instrumentation

1. Primary camera port – 6 mm Hasson
2. 2 secondary 5 mm ports (the author prefers 5 mm Endopath Xcel® trocars)
3. 30-degree 5 mm telescope
4. Kelly forceps (×2) for dissection
5. Metzenbaum scissors
6. LigaSure® for coagulation/division of vessels or 5 mm endoclips
7. Endopouch® for specimen retrieval

Position and Key Landmarks

The patient (P) is positioned fully prone for the operation. The monitor and stack system (AV) should be placed on the side opposite to the adrenal gland/mass to be removed, towards the head of the table, with the screen pointing towards the pelvis. The scrub nurse (N) should be positioned adjacent to the laparoscopic stack, with the operating surgeon (S) and assistant (A) both on the side of the lesion (Fig. 11.1). The patient is positioned at the edge of the table to allow free movement of the laparoscopic instruments. Two small supports are placed under the hips and chest of the patient, allowing the abdomen to be suspended. This reduces the contact of the intraperitoneal organs with the retroperitoneum. Once position is ready, the patient should not be moved and before skin preparation the landmarks are drawn as shown (Fig. 11.2).

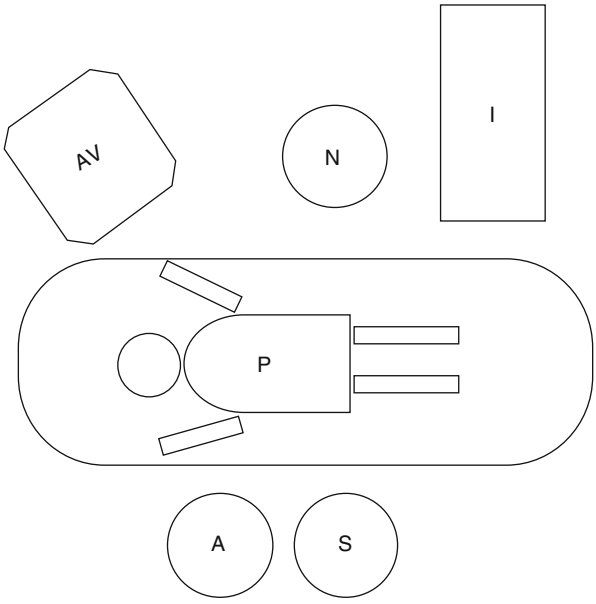

Fig. 11.1 Schematic representation of the room setup. *P* patient, *AV* audiovisual equipment, *N* scrub nurse, *I* instrument trolley, *S* surgeon, *A* camera holder

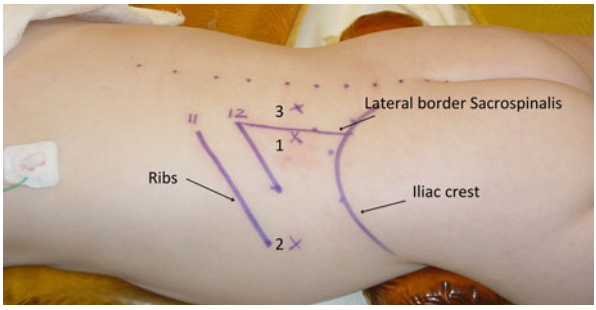

Fig. 11.2 Schematic representation of port position. *1* Camera port, *2* First instrument port, *3* Second instrument port

Anesthesia

Endotracheal intubation is required in all cases using either a cuffed or reinforced endotracheal tube that is securely fastened to prevent tube dislodgement when the child is positioned prone for the surgery. Preoperative and postoperative analgesia is provided by preemptive local infiltration of the planned incisions with 0.25 % bupivacaine.

Operative Technique

General Principles

The operative strategy is based on complete dissection of the adrenal gland outside the surrounding adipose tissue. This minimizes bleeding, which can occur with dissection on the surface of the gland. A left adrenalectomy is more difficult than a right adrenalectomy because of the absence of clear landmarks, such as the vena cava, the smaller size of the gland, and adrenal vein. The key to success is to begin dissection on the medial aspect to identify and ligate the vessels from an early stage in the operation.

Retroperitoneoscopic Adrenalectomy (Videos 11.1, 11.2)

1. The patient is positioned fully prone under general anesthesia. The exposed dorsal and lateral aspects of the trunk are prepared and draped in a sterile manner. Topographic landmarks and anticipated port sites are marked as shown (Fig. 11.2).
2. The retroperitoneal space is created outside Gerota's fascia using the technique described by Gaur [9]. Several balloons are available for creation of the retroperitoneal space. However, the authors prefer a simple and inexpensive balloon made by securing the finger of a sterile surgical glove to the end of a 12 Fr Jacques catheter with a silk tie. The catheter is connected to a three-way tap and a 50 ml Luer lock syringe. Depending on the size of the patient, 100–250 ml of air is injected slowly to develop the retroperitoneal space. The system is left inflated for 2 min to promote hemostasis and is then deflated and withdrawn.
3. Insertion of primary and secondary ports: A 6 mm Hasson cannula is inserted into the port site, followed by insufflation of the retroperitoneum with CO_2 to pressure of 10–12 mmHg. A suture to the skin secures the Hasson port. A 5 mm instrument port is placed under direct vision below the tip of the 11th rib and above the iliac crest. If necessary, a second working port (5 mm) can be placed through the paravertebral muscles.
4. Exposure of the kidney: Gerota's fascia is incised longitudinally adjacent to the posterior abdominal wall using scissors. The adventitious tissue is divided to gain adequate exposure and working space for the procedure.

5. Exposure of the posterior surface of the kidney: the kidney is dissected commencing at the apex and along the medial aspect. Using blunt dissection and gentle pressure, the kidney is reflected anteromedially to expose the posterolateral aspect of the kidney. The lateral and inferior attachments are not divided at this stage as they anchor the kidney in position and aid in exposure of the upper pole. The inferior margin of the adrenal gland can then be visualized at the superomedial border of the kidney.
6. Division of the adrenal vessels: The vessels are divided between hemoclips or with a LigaSure® when the vessels are less than 8 mm in diameter. A minimum of three clips should be applied on all vessels, with at least two clips remaining on the proximal stump of the divided vessel.
7. Removal of the gland: Once the vascular supply to the adrenal gland is completely divided, the gland is fully mobilized and freed of all attachments using either monopolar diathermy or a LigaSure®. The gland is then placed within an endobag and removed through the camera port incision, which can be slightly enlarged to facilitate removal.

Postoperative Management

1. Patient can start fluids and diet on return to the ward.
2. Frequent blood pressure monitoring in a specialized unit (nephrology ward/intensive care unit) under the supervision of a nephrologist and endocrinologist.
3. The patient is discharged when the blood pressure control has been stabilized.

Complications

Peritoneal Tear

The posterior prone approach minimizes the risk of a peritoneal tear when compared with other approaches for retroperitoneoscopic surgery. It can occur if the balloon is inflated too rapidly, when the balloon is too small for the size of the patient and in adolescents.

Balloon Rupture

Rupture of the dissecting balloon can occur when the balloon is inflated too rapidly, with over inflation of the balloon or when excessive external pressure is applied over the balloon. When it occurs the ruptured balloon must be carefully examined for lost fragments, which should be sought and removed from the patient.

Intraoperative Bleeding

Intraoperative bleeding is most likely the result of the slipping of hemoclips from an adrenal vein or because of inadvertent damage to an adrenal vein or vena cava by a laparoscopic instrument. In most cases, hemorrhage can be controlled by the prompt application of hemoclips to the affected vessel. Uncontrollable hemorrhage will require conversion to an open approach to ligate the bleeding vessel.

Author's Experience

At our institution, we have performed 14 retroperitoneoscopic adrenalectomies in 12 patients, including 2 bilateral synchronous adrenalectomies. Our patients comprised 7 boys and 5 girls, with a mean age at the time of surgery of 6 years (range, 2 months–15 years). Presentation was with hypertension ($n=4$), Cushing's syndrome ($n=3$), abdominal pain ($n=2$), virilization ($n=2$), and incidental finding on imaging ($n=1$). Our mean operative time is 124 min (range, 70–186 min). A single instrument port adrenalectomy technique was performed in four children. Histopathological diagnoses included adrenal cyst, pheochromocytoma, adrenal cortical tumor, ACTH-dependant Cushing disease, and neuroblastoma. In these children, all lesions were completely excised, and all patients have remained symptom free with a mean follow-up of 20 months.

These cases represent our experience with retroperitoneoscopic adrenalectomy. The general learning curve for laparoscopy has been long since surmounted for the senior reporting surgeon, and this experience has proved vital to expand our repertoire as a result of such encouraging results. The technique confers excellent intraoperative hemodynamic stability, and we consider the retroperitoneoscopic approach the technique of choice for adrenal surgery.

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Chapter 12
Operative Pneumovesicoscopy

Jean-Stéphane Valla

Abstract Pneumovesicoscopy is a feasible procedure; its goal is to reduce the abdominal and bladder wall trauma. Its potential advantages are a shorter hospital stay and rapid recovery with good cosmetic results. It is as efficient as classical open surgery but it needs a quite steep learning curve and has some limitations. Pneumovesicoscopy could replace all the procedures performed by a large cystostomy in classical open surgery, like correction of vesicoureteral reflux, ureteral obstruction, ureterocele, bladder diverticulum, and bladder stone removal. This technique can be considered as a useful addition to the urological armamentarium of all pediatric urologists.

Keywords Pneumovesicoscopy • Transvesicoscopic access • Ureteral reimplantation • Ureterocelectomy • Excision of bladder diverticulum • Bladder stone • Bladder neck surgery

The principle of pneumovesicoscopy (Fig. 12.1), also called pneumovesicum technique or transvesicoscopic access, is:

1. To insufflate the bladder with a gas (carbon dioxide) that allows creation of a working space equal to the bladder capacity and to provide a clear intravesical vision, much better than the vision in a liquid filled bladder.
2. To introduce in this distended natural cavity through suprapubic ports, three trocars, one median for the telescope, and two lateral for operative instruments; such a setup provides a familiar forward intravesical view toward the trigone and the ureteric orifices that is similar to that obtained with an open bladder incision [1]. So the ergonomic position for working is well adapted.

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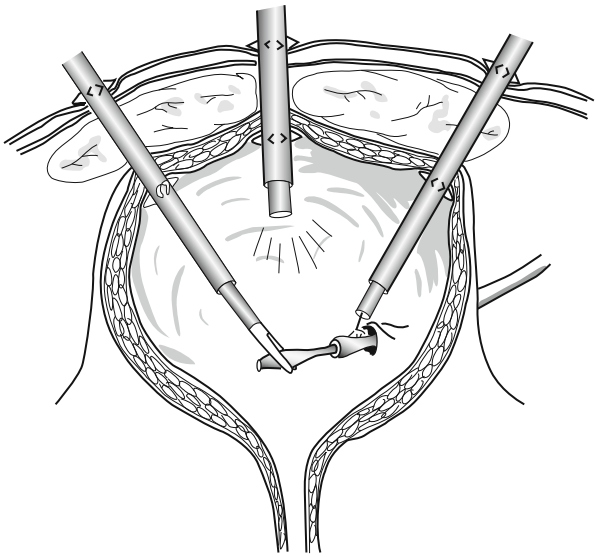

Fig. 12.1 Principle of ureteral reimplantation under pneumovesicoscopy

The goal of pneumovesicoscopy is to reduce the morbidity associated with the classical abdominal and bladder wall incision while maintaining the same good results achieved by open surgery.

Initially, operative pneumovesicoscopy was performed to correct vesicoureteral reflux; however, this technique is evolving, and its application is gradually widening to other indications like obstructive mega ureter, ureterocele, bladder diverticulum, bladder lithiasis, and bladder neck surgery for incontinence.

Limitations and Contraindications

- Related to the surgeon:
- All the vesicoscopic procedures are challenging: Expertise in intracorporeal suturing in confined spaces with fine 5/0 or 6/0 suture is essential; there is a tremendous learning curve; in short these procedures are still reserved to expert laparoscopic pediatric surgeons.
- Related to the patient:
  - The major limiting factor is the bladder capacity. The smaller the bladder, the more reduce the working space. Even if our youngest patients was 4 months old, the decreased working space does make the procedure more technically demanding and may obviate the advantages of vesicoscopic repair. Hence, this method seems difficult to apply under 1 year of age (or in bladder less than 100 ml). That explains why the use of robot, even if it seems theoretically a good solution, is not in fact the way to solve the problem [2]. In the publication of Marchini [3], patients under 4 years or with a bladder capacity less than 200 ml were excluded.

- Another limiting factor is the bladder wall conditions: in case of markedly thickened or inflamed bladder wall, the procedure could be quite difficult.
- However, previous failed injection therapy or previous intra- or extravesical surgery should not be considered a contraindication. This technique is also workable in augmented bladder.

Technique

The details concerning preparation, special equipment, muscle relaxation, positioning of patient, crew, monitors, and equipment have been already described [1, 4] and have not changed since the first edition. However, several technical points have been modified to simplify the process and avoid any disturbance or complication.

Port placement can be tricky; the specific problem of pneumovesicoscopy is, when introducing the ports, to go through two walls, firstly abdominal wall then the bladder wall and during the procedure to avoid any dislodgment of the trocar out of the bladder. Suspending the bladder to the anterior abdominal wall and fixation of the trocar to the abdominal wall are of upmost importance.

In the previous description, the bladder was distended with normal saline fluid as in classical cystoscopy, and the 3 trocars were introduced under cystoscopic control. Now the bladder is filled with gas during the first cystoscopic step, and only the first median trocar is introduced under cystoscopic control. Of course filling the bladder with liquid offers a better counter pressure than with gas, and it can be an advantage because the bladder wall is particularly soft in children and can be distorted or pushed away by the trocar tip before being entered; but we changed for CO_2 insufflation for two reasons: first, blood oozing from the bladder port sites could cloud the cystoscopic irrigation fluid; secondly, any liquid extravasation out of the bladder could occur and lead to collapse of the bladder and poor visibility.

Pneumovesicum is created after having emptied the bladder (transurethral catheter + Crede maneuver) using CO_2 introduced through the irrigation channel of the rigid cystoscope at maximal pressure of 10–15 mmHg. Once the bladder is distended, the dome is fixed to the abdominal wall under cystoscopic guidance; if the abdominal wall is thin, a percutaneous transfixing, 2/0 or 0/0 suture with a curved needle, is sufficient, quick, and effective; in case of thick abdominal wall, more time and two additional instruments are needed: one endoscopic grasper passed through the operating channel of the cystoscope in order to manipulate the thread into the bladder and one suture passer (suture passer 1 GSPO1 GORE) to introduce and extract the thread. This suture passer technique replaces the technique using two angiocath described by CK Yeung and reduces time required for this maneuver. Once the bladder wall is tightly secured to the abdominal wall, the 5 mm port is introduce through the dome; then the surgical team moves to adopt the "pneumovesicoscopic position"; the vision provided by the 5 mm telescope is much better than the cystoscopic vision; the surgeon stands in line with the trigone and the screen. An operating instrument usually a grasper could be introduced through the urethra in girls as well as in boys to replace the cystoscopic grasping forceps. The lateral suture for bladder suspension are placed according the same technique used for the dome.

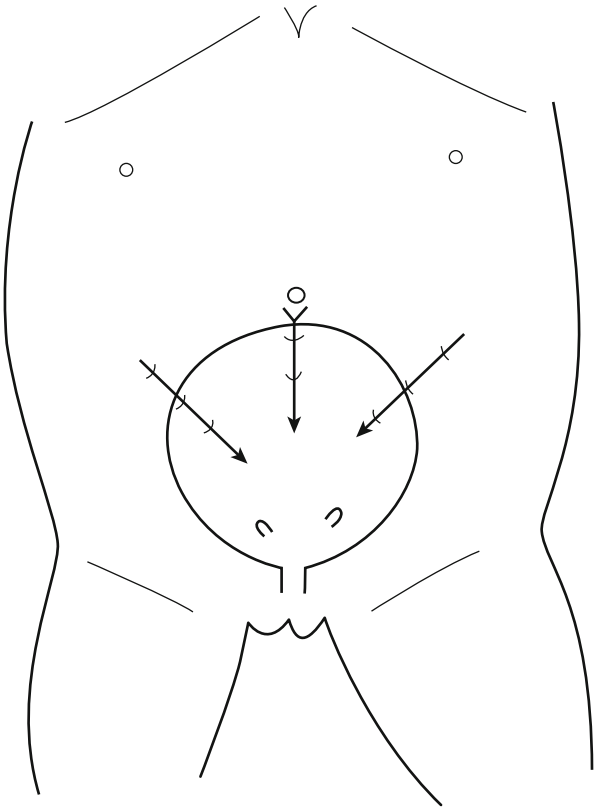

Fig. 12.2 Introduction of trocars in young children (3–5 years): in the abdominal bladder, a trocar through the interior wall of the bladder, with the tip of the trocar turned toward the lower part of the bladder

The position selected for insertion of the ports in the abdominal wall could vary according to the size of the patients; in small children younger than 3 or 4 years (Fig. 12.2), the bladder is located in a more superior position, and the trocars are more close to the umbilicus, carrying the risk of peritoneal penetration; in older children (Fig. 12.3), the bladder is deeper and lower in the pelvis: the lateral trocars are closer to the bikini line, carrying the risk of epigastric vessel injury; for the lateral working port, usually 3 mm of diameter, the penetration point in the bladder must be chosen carefully because if they are placed too inferiorly, the ports will be right on the orifice. Introducing a fine needle before the lateral trocar allows to visualize the right direction, the right depth and to put the trocar in the right position at the first attempt, avoiding multiple mucosal perforations.

As locking trocars (autosuture, Pediport Vigon) are no more available, the choice is reduced to normal reusable trocar or disposable self-expandable trocar (step ports 3 or 5 mm inner Dyne USA); the step ports are safe (blunt needle), quite easy to introduce, but expensive; the normal reusable trocar are sharp, must be cautiously

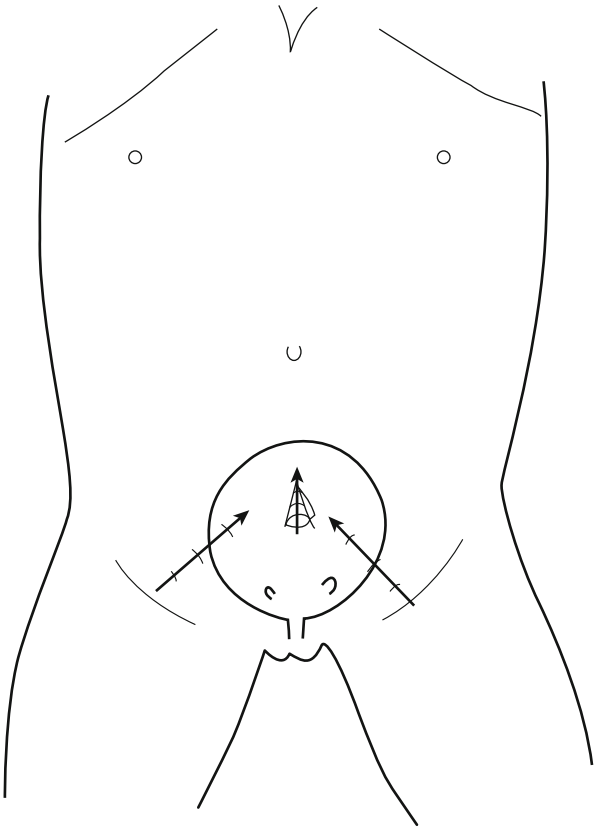

Fig. 12.3 Introduction of trocars in children older than 5 years of age: with the bladder deep in the pelvis, the trocar is inserted through the lateral wall of the bladder, with the tip of the trocar turned toward the upper part of the bladder

manipulated, but have a better penetrating index. At anytime during the procedure, a third 3 mm operating instrument could be passed through the urethra if needed.

A camera holder – mechanical, pneumatic, and robotic – is useful to achieve stability of vision, especially when suturing: as for all reconstructive surgery in a confined space, this point seems crucial.

At the end of the procedure, the trocars are extracted: if it seems possible to leave all trocar holes open reckoning on spontaneous healing with time and bladder drainage, my position is not so optimistic and more qualified; concerning the 3 mm lateral holes, especially if the trocar course through the bladder wall is oblique, that is to say that the mucosal hole is out of line with the detrusor hole, I agree with them that the port site could be left open; but all 5 mm port sites, whatever the patient age or the bladder wall thickness, must be closed to avoid any bladder leak during the postoperative period.

Some surgeons [1, 5, 6] recommend to place the suspension suture around the trocar at the beginning of the procedure and just to tie it at the end. For the two lateral holes, I used the suture passer under vision control by the telescope; the third 5 mm median hole could be closed under direct vision control; during this last step continuous bladder insufflation through the urethral catheter could facilitate the

location of bladder mucosal edges; after tying the knot, if no gas leak is audible, the maneuver is considered successful, and bladder drainage could be removed early during the postoperative period (1–3 days).

Complications

Some complications are directly related to the pneumovesicum technique. During the trocar introduction, an injury could occur on bladder floor, epigastric, or iliac vessels; during the procedure failure to reinsert the working port after its dislodgment could lead to conversion; gas leak could occur into the perivesical space, the scrotum without adverse effects, but gas leak in the peritoneal cavity must be evacuated with a transumbilical Veress needle. In the early postoperative period, urine extravasation in the perivesical space or intraperitoneal cavity or both could lead to reoperation by open surgery.

Indications and Results

Vesicoureteral Reflux

The technique has been already described [1, 4–6], but some details must be underlined because as in open surgery, some complications could occur.

During the dissection the feeding tube introduced in the ureter could migrate proximal to the ureteric orifice requiring a ureteroscopy to extract it; so a solid fixation of the feeding tube to the ureteral orifice is mandatory.

During the postoperative period, the most feared complication is ureteral obstruction usually due to a too close dissection with monopolar hook (ischemia + burn): low power setting on the hook electrode and cautery away from the ureter are recommended.

Of course as part of minimally invasive procedures, pneumovesicoscopic cure of vesicoureteral reflux is in competition with injection therapy using dextranomer hyaluronic acid; however, both techniques could be associated during the same procedure in case of bilateral disease (three cases in my experience): for example, low grade reflux on one side and obstructive mega ureter or ureterocele on the contralateral side; the "sting" performed during the cystoscopy prevents the need for bilateral reimplantation and saves time.

Several series of Cohen pneumovesicoscopic reimplantation have been published since 10 years with good results [1, 4–6]. Since our first publication in 2009 of about 75 cases [4], our total number adds up to 150 cases with the same good results: 92 % of success. Two but short comparative series underline the advantages of pneumovesicoscopy compared to open surgery [3, 7].

Megaureter

A distended ureter requires a long submucosal tunnel and sometimes a tapering, so to reimplant a dilated ureter is more difficult than to reimplant a nondilated ureter: that is true in open surgery; that is even more true with pneumovesicoscopy because to manipulate a voluminous ureter in a small bladder is tricky; to get a global view of the entire distal ureter is often impossible. In open surgery the surgeon usually performs an extra- and an intravesical approach; this is quite impossible with minimally invasive techniques: the surgeons have to make the choice of an intravesical access (pneumovesicoscopy) or an extravesical access; my experience of pneumovesicoscopy to cure an obstructive megaureter is limited to 16 cases: we have had to convert four cases in children less than 1 year of age. Excisional ureteral tapering (five cases) was not performed intravesically as described by Bi [8]; in order to save time we have preferred to exteriorize the distal part of the ureter through the urethra in girls or through the ipsilateral trocar in boys and to perform an extracorporeal tapering. A redo open ureteral reimplantation was needed 3 months after pneumovesicoscopic procedure for symptomatic ureteral stricture after tailoring. Four cases presented a pathological postoperative reflux of which two needed an injection therapy.

So as in open surgery the results are not so satisfying; all megaureters have been reimplanted according the *COHEN* technique; the classical open procedure like *POLITANO-LEADBETTER* reimplantation or psoas-hitch procedure are not feasible, restricting the surgeon's choices. So in my opinion, operative pneumovesicoscopy for obstructive megaureter should be indicated only in selected cases; in case of huge megaureter or child under 1 year, endoscopic management dilatation and stenting or laparoscopic intracorporeal or extracorporeal ureteral tapering and ureteroneocystostomy according to *LICH-GREGOIR* could be a better option [9].

Ureterocele

In case of ureterocele the treatment options must be individualized, based on the unique anatomy, pathophysiology, and renal function found in each patient. These options are simple surveillance, medical therapy, endoscopic incision, upper-pole heminephrectomy, ureteropyelostomy, excision of the ureterocele and ureteral reimplantation, and finally total reconstruction combining renal surgery plus bladder surgery during the same procedure; concerning these last two options, pneumovesicoscopy could have a part.

– In case of ureterocele associated with a well-functioning upper-pole moiety, pneumovesicoscopy allows to perform excision of ureterocele followed by bladder-base reconstruction and a double-barrel ureteric reimplantation; in that indication our experience is limited to three cases, no conversion, and three good results with a mean follow-up of 3 years.

– In case of nonfunctioning upper pole, the optimal management of ureterocele remains challenging and controversial. Even if Yeung [10] described the transperitoneal approach as "one-stage radical treatment" in a single operative session, it is also possible to use two different and specifically urological accesses: one retroperitoneoscopy to perform the upper-pole nephrectomy followed by a pneumovesicoscopy to perform the ureterocele excision (including the lower part of the dilated ureter) repair of the bladder-base defect and intravesical reimplantation of the lower moiety ureter. Of course during the same general anesthesia, two sessions are needed: the first one with the patient in lateral or prone position and the second one in supine position; but the total operative time (4 h) is similar to the transperitoneal approach. We have operated ten cases, mean age 2.5 years, no conversion, and with a mean follow-up of 4 years: 9 successes, 0 obstruction, and 1 persistent reflux on the opposite side.

In conclusion, the single-stage minimally invasive surgery for this complex anomaly, whatever the access pneumovesicoscopic or laparoscopic (more recommended in small infants), allows the completion of all necessary procedures in one stage while reducing the parietal wall trauma of the lumbar and suprapubic area.

Bladder Stone

The incidence of bladder stone formation in children is rare except in two situations:

– In developing countries endemic urinary bladder stone in children occurs mainly in boys younger than 5 years [11]: the nucleus and the main component is then ammonium acid urate.
– In developed countries the incidence of bladder stone is becoming more frequent as the number of patients with augmented bladder and continent pouches increases; in that case the main component is struvite [12].

Contrary to the adult population, the transurethral lithotripsy is restricted in children by the narrow caliber of the urethra which is either a normal small sensitive urethra or a fibrous, fragile reconstructed urethra.

The technique of percutaneous cystolithotomy has been described many years ago but only using a fluid distension of the bladder; some complications related to fluid filling have been reported: hyperthermia and extravasation of fluid in the perivesical space or in the peritoneal cavity [12]; CO_2 insufflations allow to avoid these complications.

The technique is straightforward: if possible, a cystoscope is introduced first through the urethra or *MITROFANOFF* conduit in order to fill the bladder with CO_2 and to allow for visual control when introducing the suprapubic port. The diameter of this port is chosen according to the size of calculi or the size of operating instrument (5–15 mm) – if no urethra or *MITROFANOFF* conduit is available, the bladder is insufflated through a suprapubic puncture with a needle (18–22 gauge) until it is

easily palpable; then a small suprapubic incision is made to introduce a 5 mm trocar and telescope taking care not to injure the bladder floor. A second suprapubic port, and sometimes a third, is introduced under visual control; it is also possible to introduce a 10 mm telescope with 5 mm operating channel. In patients who previously had an augmentation cystoplasty, the incision should be made as low as possible to avoid violation of the peritoneum; the site of puncture is transilluminated and examined visually to ensure there is no intervening tissue.

The way for stone extraction varies according to their size and their number. The goal is to remove all the stones and not to leave any small fragments behind, which could serve as a nidus for further stone formation, especially in an abnormal bladder as after cystoplasty. In case of calculi that are less than 8 mm in diameter, suction with a tube is an easiest way. Grasping forceps could also be used taking care not to break the stone in pieces. Stones larger than 15 mm must be extracted after fragmentation; the usual mechanical means, electro-hydraulic, ultrasonic, and pneumatic lithotripsy cannot be used in air; all the stones must be introduced in a small bag (piece of glove filled with liquid) and extracted after mechanical lithotripsy. Stone larger than 30 mm is best managed by the classic open cystolithotomy.

At the end of procedure a visual check is mandatory; if residual stones are suspected, an X-ray is performed and fluoroscopy is carried out. The porthole is sutured around a suprapubic catheter placed for straight drainage for 2–5 days depending on the status of the bladder.

The results are good in the literature between 80 and 100 % of patient rendered stone-free with very few complications [11, 12]. Our short series [13] of 12 cases supports these good results: only one conversion (stone larger than 35 mm in an exstrophic bladder), no complication, all patients are stone-free, and 2 recurrences in the long term.

In conclusion, pneumovesicoscopic vesicolithotomy provides a minimally invasive means of extracting vesical calculi; it avoids any damage of the urethra and reduces trauma to the bladder. It is a very simple procedure with practically no learning curve. The smaller the calculus, the easier the procedure. That is why a follow-up protocol with frequent bladder imaging in patients with a known predisposition of vesicolithiasis is of upmost importance, as well as all the strategies to prevent recurrences.

Bladder Diverticulum

Congenital bladder diverticulum is a rare anomaly occurring mainly in boys, often associated with VUR; surgical excision of the diverticulum with or without ureteral reimplantation is indicated in case of symptomatic children.

Different classical surgical approaches have been described including the extravesical and intravesical approaches; minimally invasive surgery offers the same choice. Comparing with the transperitoneal access, the pneumovesicoscopy allows to easily identify the diverticular orifice, to complete the diverticulum excision, and to reimplant the ureter if needed, avoiding any violation of the peritoneum. Usually

the diverticular hiatus is located on the bladder floor, on the opposite side of the dome where the ports are introduced, putting the surgeon in a good ergonomic position; in my mind the only indication for a transperitoneal laparoscopy is a diverticulum located in the posterior bladder wall without associated reflux.

The first step is a cystoscopy to see the mouth of the diverticulum, to localize the ureteral orifice – away, near, or inside the diverticulum. A ureteric catheter is inserted to spot the ureteric orifice and the distal ureter during the whole procedure. Dissection of the diverticulum is started by creating the plane between the mucous wall of the diverticulum and the detrusor muscle; the diverticulum is progressively inverted inside the bladder and completely freed, taking care not to injure the deferent and the ureter. The bladder wall defect is closed by interrupted sutures. If needed the ureter is reimplanted.

We operated on six boys with a mean age of 8 years; five cases needed a concomitant ureteral reimplantation, no conversion; after a mean follow-up of 2 years, all patients were free of symptoms with a normal bladder ultrasound. Other publications [14] confirm the feasibility with an acceptable learning curve and the high success rate, but the number of cases is still limited.

Bladder Neck Reconstruction

The treatment of an incompetent bladder neck remains a difficult challenge; several techniques have been described for incontinence in case of neurogenic bladder or exstrophic bladder. According to the approach, these techniques could be divided in two groups:

- Extravesicourethral approach: fascial sling or suspension of the urethra could be performed with a prevesical laparoscopic access; artificial urinary sphincter needs a classical open surgery.
- Intravesicourethral approach: injection of bulking agents, narrowing urethra and bladder neck using the *YOUNG-DEES* technique, creation of an intravesical neourethra with a flap valve mechanism according to *KROPP* technique or *PIPPI SALLE* technique, and finally bladder neck closure. All these techniques through an intravesical approach could be realized using pneumovesicoscopy, according to the technique described by Yeung [15].

Unfortunately no series have been published; I have no personal experience except few cases of injection of bulking agents; so it seems difficult to assess the results.

Conclusion

Operative pneumovesicoscopy is only a new therapeutic possibility between pure endoscopic procedure and open surgery. It is now proven that this technique represents an improvement compared to open surgery: it is as safe and as efficient in

expert hands. That is why it must be mastered by all pediatric urologists and should be proposed as an option to the family each time an intravesical operative is scheduled. However, some progress remains to be made in order to achieve the "ideal" minimally invasive bladder surgery, that is to say day surgery without drainage.

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Chapter 13
Laparoscopic Extravesical Reimplantation

François Varlet and Manuel Lopez

Abstract The posterior wall of the bladder is easily approached by laparoscopy and allows for a nerve-sparing extravesical unilateral or bilateral reimplantation according to the Lich-Gregoir technique. It is performed with a 5 mm telescope and two 3 mm instruments. The exposure of the posterior wall is helped by transparietal bladder suspension. The postoperative period is comfortable without hematuria and bladder spasms. No bladder catheter is necessary, and it is possible to discharge the child quickly from the hospital. The success rate is about 95 % with no documented voiding dysfunction postoperatively. Furthermore, the ureteral meatus is always in its initial position, allowing easier endourology in the future if necessary.

Keywords Extravesical • Reimplantation • Laparoscopy • Child • Lich • Gregoir

Introduction

Vesicoureteral reflux (VUR) is a frequent pathology, mainly in females of school-going age and secondary to bladder dysfunction. Vesicoureteral reflux resolves in a lot of patients with education regarding good micturition habits and medical treatment, especially against constipation. However, some children have to be operated because of repeated pyelonephritis in spite of well-conducted treatment or decreasing of the renal function on radionuclide scan. Malformations as duplex system are often associated with vesicoureteral reflux and may also require a reimplantation. There are a number of techniques of reimplantation to correct VUR, and one of them is the Lich-Gregoir procedure [1, 2]. This technique is often used for unilateral reflux, but has been used sparingly for bilateral reflux because of a 10 % incidence

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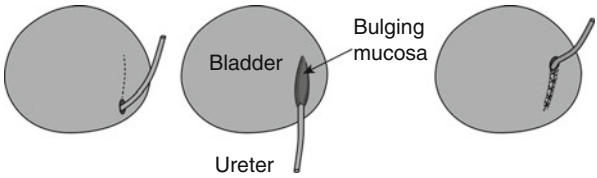

Fig. 13.1 Lich-Gregoir procedure

of postoperative urinary retention [3]. With laparoscopy, the approach to the posterior wall of the bladder is easy, and the dissection of the bladder is dramatically less important, allowing a nerve-sparing procedure and possible bilateral reimplantation [4]. Because of good results with open technique in unilateral reflux with short hospitalization, the laparoscopic extravesical reimplantation (LER) was developed for unilateral and bilateral reflux [5].

Specific Instrumentation

To perform a LER, different instruments are required:

- A 30° 5–10 mm telescope according to the age of child. It is very important to have a 30° telescope for a good exposure of the posterior bladder wall during the muscular section and muscular suture.
- 3 mm instruments: atraumatic graspers, dissector, monopolar scissors, and needle holder.
- Two 3 mm ports for these instruments.
- A "lace or ribbon."
- An 8–12 Fr bladder catheter.
- A 60 ml bladder syringe to empty or to fill the bladder during the procedure.

Operative Technique

The LER is the same procedure described by Lich and Gregoir (Fig. 13.1), but by a transperitoneal approach.

A broad-spectrum antibiotic is routinely administered intravenously on induction of general anesthesia. A cystoscopy may be performed initially if bladder control is required, especially in children with a duplex system to assess the location of the ureteral orifices and to check the anatomy. Sometimes in these duplex systems, when an upper pole nephrectomy is scheduled during the same operation, a ureteral catheter can be placed in one of the two ureters to facilitate its recognition during the nephrectomy; otherwise, the ureterocele can be opened widely during the endoscopy before the upper pole nephrectomy and LER of the two ipsilateral ureters. In other circumstances, for example, bilateral reflux with ipsilateral grade I and

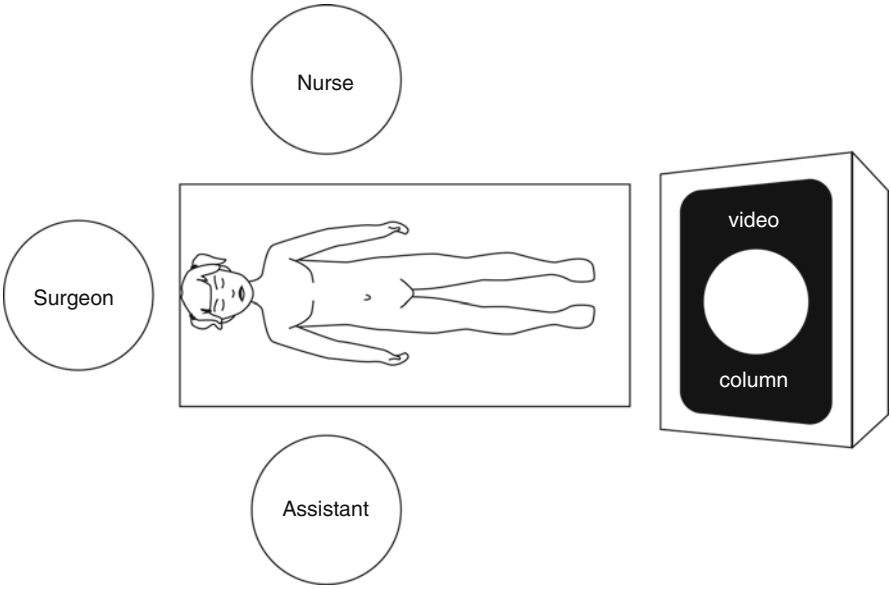

Fig. 13.2 Position of the crew and equipment. The head of patient is close from the edge of the table. The surgeon, the telescope, the bladder, and the monitor form a straight line

contralateral grade III VUR, it is possible to do an endoscopic subureteric injection (STING procedure) to treat the grade I reflux before LER of the grade III reflux.

At the end of the cystoscopy, the child is placed in a supine position on the table with legs apart; the table is adapted to the size of the child to allow a good position of the video column, the closest as possible to the feet, to avoid a monitor too far from the surgeon (Fig. 13.2). After preparation of the abdominal wall, an urethral catheter is placed, and the bladder is emptied to allow a good vision of the pelvic cavity. The surgeon is positioned at the head of the patient; when the child is too old, he or she must to be placed laterally, on the right side for the left ureter and on the left side for the right ureter. The assistant and the nurse are placed according the position of the surgeon (Fig. 13.3).

The laparoscopy is performed through a lateral or trans-umbilical incision under vision, and a 5 mm trocar is introduced for the telescope. The two 3 mm trocars are placed under direct vision at the left and right abdomen and at the same level from the umbilicus. When the child is small, the trocars are higher, and in adolescent they are in the lower part of the abdomen (Fig. 13.4).

The first step is to release the ureter from the level of iliac vessels to the posterior wall of the bladder. The peritoneum is opened just under the iliac vessels, and the ureter is grasped and released for a few centimeters. A ribbon is placed around it to avoid ureteral trauma. The ureteral vessels are coagulated far from the ureter, and progressively it is dissected down to the bladder wall. In girls, the fallopian tube and the ovary have to be pushed laterally to allow this dissection; at the end of this step,

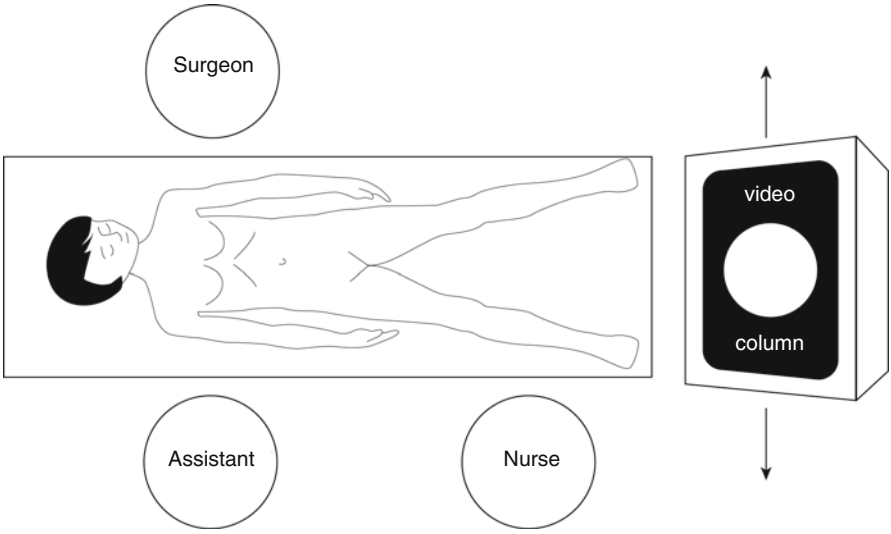

Fig. 13.3 Position with a larger child

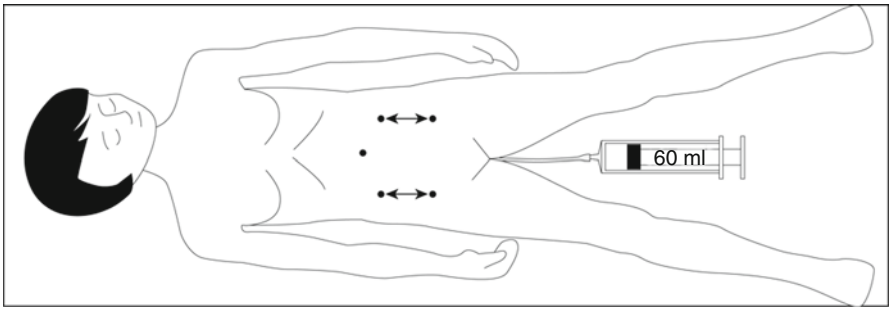

Fig. 13.4 Position of trocars, more or less high according the size of patient. A sterile 60 ml syringe is set up into the bladder catheter to empty or fill the bladder during procedure

the mesosalpinx is opened forward, and the ureter is pull up through this opening (Fig. 13.5); the ureter is mobilized to achieve sufficient freedom for a tension-free reimplantation keeping in mind the uterine vessels which have to be respected. In the boy, the vas deferens is pushed down and up to allows its good mobilization and no subsequent ureteral stricture (Fig. 13.6). During this entire step, the bladder has to be empty.

With the pulling up of the ureter, the axis of the muscular trench is seen on the posterior wall of the bladder and a few coagulations are done on the peritoneum to mark the future muscular section. The bladder is filled with 50–100 ml of normal saline to get a good exposure of the posterior wall and one or two transperitoneal stitches are placed just above the site of muscular section. At this moment the light

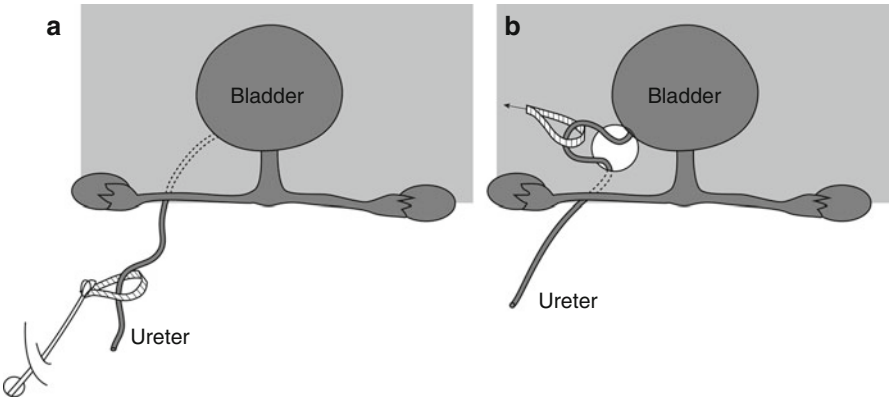

Fig. 13.5 After ureteral dissection behind the fallopian tube (**a**), the mesosalpinx is opened forward to pull up the ureter and to release it close to its entry in the bladder (**b**)

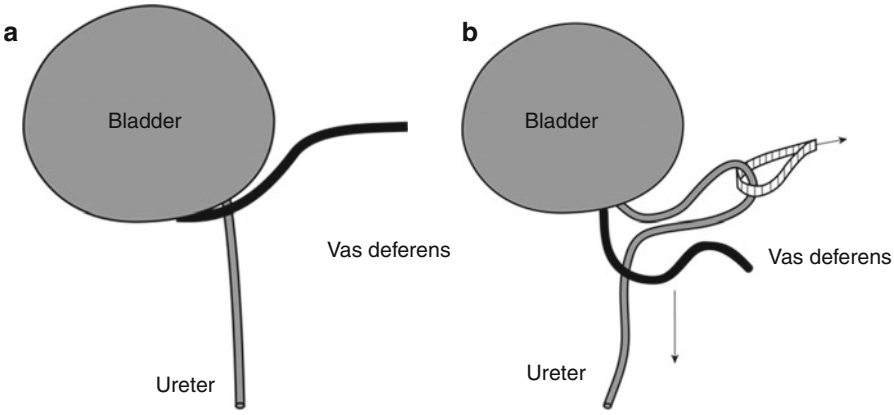

Fig. 13.6 Mobilization of vas deferens: (**a**) before dissection, (**b**) after dissection

cable is turned to have a 30° vision. The section of the detrusor is begun with monopolar scissors. After coagulation, the muscle is cautiously cut in the upper part of the bladder until to see the mucosa, with its characteristic blue coloration and protrusion. Then, the muscle and the mucosa are released down on 3 or 4 cm (×5 ureteral diameter). The trench ends at the level of the terminal part of the ureter; in this lower part, there are frequently small vessels that you have to coagulate to avoid bleeding. A monopolar hook can be used too, but the scissors are more precise in our opinion. If a mucosal perforation occurs, this is closed with an absorbable loop: when it is in the abdominal cavity, the hole is grasped with the dissector, and the loop is tied around it; this allows the procedure to proceed. Another solution is to empty the bladder and to suture the mucosa with interrupted or running 5-0 absorbable suture. To lay the ureter on the mucosa, another transperitoneal suspension is

done through the abdominal wall and the ureteral ribbon, respecting the long axis of the trench. Then, the detrusor is reapproximated with 4-0 or 3-0, according the bladder size, absorbable sutures. To get a correct lower suture, it is advised to do the lower stitch first to get a good view of the terminal part of the ureter. This is an important point when a paraureteral diverticulum is present. In the girl, the uterine vessels are left between mucosa and ureter; in the boy, the vas deferens is placed above and behind the ureter. In case of duplex system, the two ureters are placed in the same trench. The new ureteral entry in the bladder has to be large enough to avoid a stricture and postoperative ureteral dilatation. At the end of the procedure, the transperitoneal suspensions of the bladder and ureter are removed, and the ureter should lie without tension. If there is too much tension, the ureter is released proximally. A peritoneal suture is usually not necessary, but if the ureter protrudes forward or laterally, the peritoneal suture allows pushing it along the pelvic wall and will avoid a possible incarceration of a small bowel loop. No drain is necessary.

In case of bilateral reflux, the same procedure is performed on the other side. The trocar position is the same, and the transperitoneal suspension is modified to get the best exposure of the posterior bladder wall for this side. In adolescents, the surgeon may have to change sides to be more comfortable.

The umbilical incision is closed with 3-0 absorbable suture through the muscle, and the skin is approximated with adhesive bands. The bladder catheter is removed.

Postoperative Management

Intravenous analgesia is required for 12–24 h, and then only simple oral analgesic is required. The child is discharged from the hospital day after surgery without antibiotics.

Author's Experience

Between 2007 and 2012, LER was done in 63 patients and 84 ureters, with a mean age of 51 months (15–183). The reimplantation was unilateral in 42 and bilateral in 21 children, and 20 had a duplex system. Five children had Hutch diverticulum. The average renal function with DMSA scintigraphy was 32 % (18–39 %).

No open conversion was necessary. Endoscopic opening of ureterocele was performed in two cases and upper pole nephrectomy in two cases. The mean operative time was 70 min in unilateral cases (38–120) and 124 min in bilateral cases (100–210). The immediate follow-up was impressive with moderate pain at day 1 treated only by simple oral analgesia and no difficulties with micturition. None of the children with bilateral reimplantation developed urinary retention, and discharge on postoperative day 1 was possible in 95 % of cases. Two children developed urinary peritonitis at postoperative day 7 and day 15 due to ureteral

perforation just above a too tight point of entry in the bladder; but at this period, we did not use the ribbon to pull the ureter during the procedure, and an excessive handling of the ureter may have resulted in local ischemia as it was reported in the early series by laparotomy [6]. They were treated by open reimplantation with Leadbetter-Politano procedure and psoas hitch in the first case and by laparoscopic ureteral suture on double J stent after enlargement of the hole of entry in the second case; this last patient had a remaining grade I reflux treated by endoscopic injection with success. A voiding cystogram was done routinely for the 30 first patients and after only in cases of recurrent pyelonephritis. The mean follow-up was 36 months and two recurrences of reflux occurred, one cured by Cohen reimplantation and one is under follow-up. Hence our success rate was 60/63 patients (95.2 %) and 81/84 ureters (96.4 %). No recurrence occurred in duplex systems LER.

Conclusion

Laparoscopic extravesical reimplantation is a good procedure to treat vesicoureteral reflux with a good success rate. This technique has the advantages of the endoscopic injection with less pain and short hospitalization, and the advantages of the Cohen technique with good results. For a unilateral reflux, LER has to be in balanced with the Lich-Gregoir technique by the open technique because this treatment is possible as a 1-day surgery. The LER is effective in duplex system, and the size of the two ureters is not a contraindication. It is also feasible for bilateral reflux because of reduced dissection and nerve sparing of the posterior wall of the bladder, and we had no episodes of postoperative urinary retention.

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Chapter 14
Bladder Diverticulectomy

David J. Chalmers and Jeffrey B. Campbell

Abstract A bladder diverticulum is a rare, congenital, or acquired defect consisting of a herniation of mucosa through the bladder musculature. Signs, symptoms, and indications for surgical intervention include hematuria, lower urinary tract symptoms, recurrent urinary tract infections, and bladder calculi. Urodynamics should be considered if the diverticulum is thought to have an obstructive etiology. A combined cystoscopic and laparoscopic approach may be employed to safely perform a bladder diverticulectomy using standard instrumentation and techniques. Etiologies, indications for surgical intervention, preoperative studies, instrumentation, and operative technique, as well as postoperative management, are described.

Keywords Bladder diverticulum • Diverticulectomy • Endourology • Laparoscopy • Pediatrics

Introduction

A bladder diverticulum is a herniation of the bladder mucosa through a defect in the bladder musculature that may be either congenital or acquired by chronic bladder outlet obstruction [1]. In the pediatric population, congenital diverticula are more common than acquired diverticula typically seen in adults in conjunction with benign prostatic hyperplasia. Children with connective tissue disorders such as Ehlers-Danlos syndrome are thought to be at higher risk for this anomaly [2]. Due to the size and location of symptomatic diverticula, surgery has classically been performed by an open, retropubic approach. More recently, laparoscopic techniques have been employed in an effort to lower operative morbidity, decrease convalescence, and improve cosmesis, while maintaining the safety and efficacy of an open procedure.

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Indications/Contraindications

Indications for surgical repair include incomplete emptying, irritative or obstructive voiding symptoms, and hematuria. In addition, urinary stasis may lead to recurrent urinary tract infections or bladder calculi. Some have argued that small, asymptomatic diverticula should be removed due to risk of future malignancy [3].

No absolute contraindications exist. However, a history of prior abdominal or pelvic surgery may complicate transperitoneal dissection and may be considered a relative contraindication to a laparoscopic approach.

Preoperative Investigations

Either cystoscopy or voiding cystourethrography may accurately diagnose and characterize bladder diverticula. Notably, about 98 % of diverticula are localized superolateral to the ureteric orifice, likely due to the orientation of the detrusor muscle fibers as they associate with the trigone [3]. These periureteric or "hutch" diverticula are commonly associated with vesicoureteral reflux [4]. If bladder outlet obstruction is suspected, urodynamics should be considered to rule out an acquired etiology.

Instrumentation

Three laparoscopic ports and a 0° or 30° laparoscope may be used. A grasper, such as a Maryland, may be used for retraction and a monopolar hook or scissors may be used for electrocautery and dissection. A needle driver and suction device should be available.

If a combined endoscopic approach is used, a rigid pediatric cystoscope is required. A small Foley catheter or occlusion balloon catheter (Fogarty catheter) may be employed to inflate a balloon within the diverticulum. A ureteral catheter or indwelling ureteral stent may be placed if the diverticulum is in close proximity to the ureter.

Patient Positioning

The patient is placed in dorsal lithotomy position for cystoscopy. The patient is then placed in the supine position for laparoscopy. Gentle Trendelenburg positioning may be employed as needed to displace the bowel cephalad by gravity.

Operative Technique

Cystoscopy may be performed to aid in identifying the location of the diverticulum. Instilling the bladder with saline typically inflates the diverticulum and allows for optimal visualization. A small Foley catheter or occlusion balloon catheter (Fogarty catheter) may be employed to inflate a balloon within the diverticulum. Alternatively, a council catheter may be passed over a wire into the diverticulum. Gentle traction may be used to occlude the neck of the diverticulum. Placement of an intradiverticular balloon may be technically challenging, but significantly aids in identifying smaller diverticula and distinguishing them from the bladder wall. A ureteral catheter may be placed if the diverticulum is in close proximity to the ureter. Alternatively, an indwelling ureteral stent may be placed with the string attached for ease of removal upon completion of the procedure. A separate Foley catheter is then placed into the bladder for drainage and irrigation as needed.

The patient is then placed in the supine position. A transumbilical incision is utilized to gain access to the peritoneal cavity. The abdomen is insufflated to an age-appropriate pressure. A working port is placed in each lower quadrant of the abdomen (Fig. 14.1).

The ureters, and vas deferens in males, are identified and the bladder is mobilized to expose the diverticulum. A hitch stitch can be used to retract the bladder. Alternatively, an additional working port may be placed in the suprapubic midline to aid with retraction. The diverticulum is mobilized circumferentially and the neck of the diverticulum is exposed. Great care is taken to avoid injury to the rectum and adjacent vagina in females. The balloon within the diverticulum is deflated and removed. The neck of the diverticulum is then ligated or transected and closed with

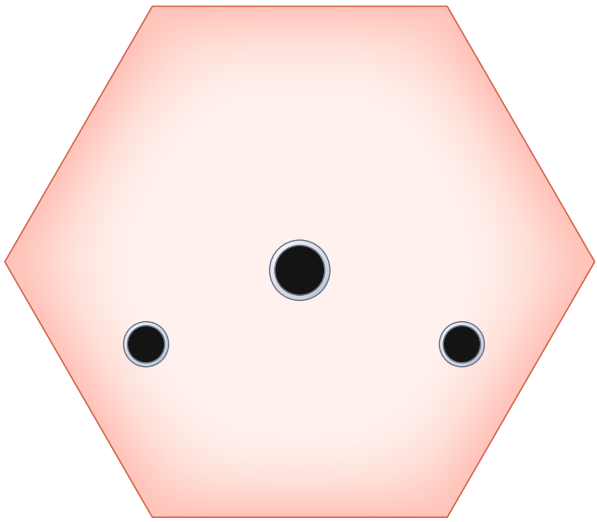

Fig. 14.1 Port placement for bladder diverticulectomy using three ports

an absorbable suture. Gentle irrigation through the urethral catheter may be used to test the integrity of the repair. The resected diverticulum is then removed through a working port or through a port site incision, which may be enlarged if necessary. A drain may be placed adjacent to the diverticulum per surgeon preference. The ports are then removed, and the port sites closed, in the usual fashion.

Postoperative Management/Complications

The Foley catheter remains in place for several days. A voiding cystourethrogram may be performed prior to removal of the catheter. If a drain is left in place, it may be removed 24–48 h after removal of the Foley catheter. If there is concern for a urine leak, a fluid creatinine level may be obtained.

Results

Bladder diverticulectomy is an uncommon procedure in the pediatric population. In the adult literature, laparoscopic diverticulectomy is associated with a shorter hospital stay, less blood loss, less postoperative pain, and longer operative times [5]. Small case series have been reported in the literature with uniformly low complication rates and excellent outcomes.

Author Remarks

Laparoscopic diverticulectomy may be performed extraperitoneally [6] or pneumovesicoscopically [7]. These approaches preserve the integrity of the peritoneum, eliminating manipulation of the bowel. In addition, if a urine leak develops, it is contained within the extraperitoneal space.

Robotic-assisted laparoscopic diverticulectomy has also been described in both pediatric [8] and adult populations [9]. At this point, it is unclear if the benefits of improved articulation and three-dimensional viewing outweigh the additional procedural costs of this technology.

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Chapter 15
Excision of Prostatic Utricle

David J. Chalmers and Jeffrey B. Campbell

Abstract A prostatic utricle is a congenital outpouching of the prostatic urethra. Signs, symptoms, and indications for surgical intervention include hematuria, pseudo-incontinence from urine trapping within the utricle, lower urinary tract symptoms, recurrent urinary tract infections, and stone formation within the pouch. A combined cystoscopic and laparoscopic approach may be employed to safely perform an utriculectomy using standard instrumentation and techniques. Etiologies, indications for surgical intervention, preoperative studies, instrumentation and operative technique, as well as postoperative management are described.

Keywords Endourology • Laparoscopy • Pediatrics • Prostatic utricle

Introduction

A prostatic utricle, or Müllerian duct cyst, is an outpouching of the prostatic urethra derived from both Müllerian and Wolffian duct origins [1]. It is an embryologic remnant likely resulting from a transient decline in fetal testicular function during the period of urethral formation [2, 3]. Not surprisingly, the incidence has been reported to be higher in association with hypospadias, particularly proximal hypospadias [4]. Indeed, an enlarged utricle is most commonly discovered when difficulty is encountered catheterizing the urethra during a hypospadias repair. In addition, an enlarged prostatic utricle may be associated with persistent Müllerian duct structures such as fallopian tubes and uterus [2]. A prostatic utricle may become symptomatic, requiring surgical excision. Adequate exposure of the utricle is challenging because of its position deep within the pelvis. Consequently, a wide variety of surgical approaches have been described, including retropubic, transvesical,

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transurethral, perineal, and posterior sagittal. The advantages of a laparoscopic approach include excellent visualization, improved cosmesis, and a higher rate of complete excision in a single setting while minimizing perioperative morbidity.

Indications/Contraindications

A prostatic utricle is most often asymptomatic but may cause a variety of signs or symptoms, including hematuria, pseudo-incontinence from urine trapping within the utricle, lower urinary tract symptoms, recurrent urinary tract infections, epididymo-orchitis, and calculus formation within the pouch. Obstruction of the ejaculatory ducts by the enlarged utricle has also been reported as a cause of infertility [5]. Furthermore, there is concern for neoplastic degeneration that has been reported to be as high as 3 % [6, 7].

Preoperative Investigations

Retrograde urethrography, voiding cystourethrography, or direct visualization by cystourethroscopy can be used to characterize a prostatic utricle. Contrast can be seen filling a tubular structure posterior to the prostate and bladder. A classification system has been proposed to characterize utricles [8]. Others have defined a clinically significant utricle as one large enough to accommodate a cystoscope to a depth of at least 2 cm [2]. Ultrasonography or MRI is an appropriate adjuvant investigation to better characterize the utricle and screen for persistent Müllerian duct structures.

Instrumentation

An appropriately sized rigid cystoscope is used for cystourethroscopy. An occlusion balloon catheter (Fogarty catheter) may be employed to inflate a balloon within the utricle.

Three laparoscopic ports and a 0° or 30° laparoscope may be used. A fourth port may be required to aid with retraction. A grasper, such as a Maryland, may be used for retraction, and a monopolar hook or scissors may be used for electrocautery and dissection. A needle driver and suction device should be available.

Patient Positioning

The patient is placed in dorsal lithotomy position for cystoscopy. The patient is then placed in the supine position for laparoscopy. Gentle Trendelenburg positioning may be employed as needed to displace the bowel cephalad by gravity.

Operative Technique

Cystoscopy may be performed to access the utricle. An occlusion balloon catheter (Fogarty catheter) may be employed to inflate a balloon within the utricle. Gentle traction may be used to occlude the neck of the diverticulum. Placement of an intrautricular balloon may be technically challenging but significantly aids in identifying the utricle and distinguishing it from the prostate. A Foley catheter may be placed into the bladder to aid in identification of the urethra and provide postoperative drainage of the bladder.

The patient is then placed in the supine position. A transumbilical incision is utilized to gain access to the peritoneal cavity. The abdomen is insufflated to an age-appropriate pressure. A working port is placed in each lower quadrant of the abdomen (Fig. 15.1).

The ureters and vas deferens are identified. The peritoneal reflection is incised transversely posterior to the bladder. A hitch stitch can be used to retract the bladder anteriorly. Alternatively, an additional working port may be placed in the suprapubic midline to aid with retraction. The presence of a balloon within the utricle significantly aids in identifying a smaller utricle and distinguishing it from the prostate, particularly when manipulated by an assistant.

The utricle is mobilized circumferentially with judicious use of needlepoint electrocautery, and the neck of the utricle is exposed. Great care is taken to avoid injury to the vas deferens and adjacent rectum. Occasionally, it is not possible to excise the whole utricle without damaging the vas deferens. In these patients, it is prudent to leave some of the utricle behind. The occlusion balloon is deflated and catheter is removed. The neck of the utricle is then ligated or transected and closed with an absorbable suture. The Foley catheter can be helpful in identifying the urethral lumen. The resected utricle is then removed through a working port or through a port site incision, which may be enlarged if necessary.

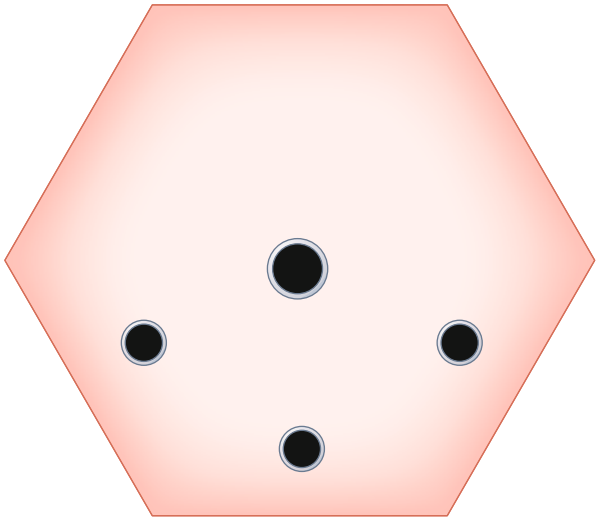

Fig. 15.1 Port placement for excision of prostatic utricle using four ports

Postoperative Management/Complications

The Foley catheter remains in place for several days. A voiding cystourethrogram may be performed prior to removal of the catheter.

If there is concern for development of a urethral stricture, a retrograde urethrogram may be indicated.

Results

Laparoscopic excision of a prostatic utricle is an uncommon procedure in the pediatric population. Case reports and small case series have been reported in the literature with uniformly low complication rates and excellent outcomes [9–11].

Author Remarks

A wide variety of surgical approaches for excision of prostatic utricles has been reported, including a transvesical approach with marsupialization between the top of the cyst and the bladder [6], transperitoneal transtrigonal approach [12], perineal approach [7, 12], and transrectal approaches [13, 14]. Endoscopic treatments have been limited to unroofing infected cysts or removal of small remnants [15, 16]. The reported success rate and morbidity of these operations appear to be significantly worse compared to recent laparoscopic series, though the number of cases is small.

Robotic-assisted laparoscopy may also be utilized. At this point, it is unclear if the benefits of improved articulation and three-dimensional viewing outweigh the additional procedural costs of this technology.

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Chapter 16
Laparoscopic-Assisted Bladder Reconstruction

David J. Chalmers and Duncan T. Wilcox

Abstract When conservative management of the neurogenic bladder fails to produce a bladder of adequate capacity or compliance, augmentation cystoplasty may be employed. It is a challenging and time-consuming procedure that is frequently performed in addition to other reconstructive procedures such as bladder neck reconstruction, appendicovesicostomy, or antegrade continence mechanism procedure. Traditionally, reconstructive surgeons have used large, midline incisions for maximal exposure in order to achieve optimal technical results. A laparoscopic-assisted technique may reduce the morbidity of a major reconstructive procedure by decreased postoperative pain, quicker convalescence, improved cosmesis, and shorter hospital stay. While pure laparoscopic and robotic-assisted reconstructions have been described, an initial laparoscopic mobilization in combination with a Pfannenstiel incision is a technique that may be accessible to most pediatric urologists while achieving the goals of minimally invasive surgery.

Keywords Pediatrics • Laparoscopy • Bladder augmentation • Endourology

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Introduction

When conservative management of the neurogenic bladder fails to produce a bladder of adequate capacity or compliance, augmentation cystoplasty may be employed. It is a challenging and time-consuming procedure that is frequently performed in addition to other reconstructive procedures such as bladder neck reconstruction, appendicovesicostomy, or antegrade continence mechanism procedure. Traditionally, reconstructive surgeons have used large, midline incisions for maximal exposure in order to achieve optimal technical results [1]. A laparoscopic-assisted technique may reduce the morbidity of a major reconstructive procedure by decreased postoperative pain, quicker convalescence, improved cosmesis, and shorter hospital stay. While pure laparoscopic- and robotic-assisted reconstructions have been described [2, 3], an initial laparoscopic mobilization in combination with a Pfannenstiel incision is a technique that may be accessible to most pediatric urologists while achieving the goals of minimally invasive surgery.

Indications/Contraindications

Myelodysplasia and myogenic failure are the most common causes of a small capacity, neuropathic bladder in the pediatric population. Occasionally, augmentation is required in order to increase capacity alone, such as in bladder exstrophy or cloacal exstrophy. When conservative measures such as anticholinergics and clean intermittent catheterization fail to produce safe storage pressures and a socially acceptable capacity, augmentation is indicated. Intravesical storage pressure >40 cm H20 is the most vigorous indication for augmentation as this has been associated with upper tract deterioration [4]. Incontinence and vesicoureteral reflux are associated symptoms that may also benefit from a larger capacity and lower-pressure system. Literature suggests that reflux commonly resolves following augmentation without the need for ureteral reimplantation [5, 6].

Absolute contraindications to transperitoneal laparoscopy include patients who cannot tolerate general anesthesia or pneumoperitoneum, which are uncommon concerns in this population. Relative contraindications include extreme obesity and prior abdominal or pelvic surgery.

Preoperative Investigations

Investigations prior to bladder reconstruction should include evaluation for renal function, including laboratory studies and imaging of the upper tracts. Urodynamics are essential to assess bladder capacity, compliance, vesicoureteral reflux status, and evaluation of the bladder outlet. A preoperative urine culture should be considered to avoid intraperitoneal contamination of infected urine. Knowledge of prior

abdominal or bowel surgery is important for selection of an appropriate bowel segment. Finally, it is important for patients and families to be thoroughly counseled and prepared regarding expectations, risks, and benefits. Significant dedication and adherence to postoperative care are essential for a successful outcome and minimizing complications. Familiarity and commitment to catheterization preoperatively have been shown to improve postoperative adherence to catheterization and bladder irrigation [1, 7].

Instrumentation

Three laparoscopic ports are used, including a 5 mm port for the camera as well as two 3/5 mm working ports. A 0° or 30° degree laparoscope may be used. Graspers, such as a Maryland and bowel grasping forceps, may be used for retraction, and a monopolar hook or scissors are used for electrocautery and dissection.

Patient Positioning/Preparation

The patient is placed in the supine position. An epidural catheter can be considered but is often contraindicated in patients with spinal dysraphism. Wound soakers, which can infuse a constant anesthetic into the incision site above and below the level of the fascia of the Pfannenstiel incision, are an excellent alternative that may be inserted near the conclusion of the procedure. Preoperative antibiotics are always given. It is not our practice to routinely use bowel preparation prior to bladder reconstruction [8, 9].

Operative Technique

General anesthesia is required and muscle paralysis is often helpful to obtain a satisfactory working space. Laparoscopy is performed with a 5 mm camera port inserted through the umbilicus and two 3/5 mm working ports, all placed under direct vision. Port placement should be chosen to optimize dissection in the right lower quadrant while maintaining access up to the hepatic flexure (see Fig. 16.1). Care should be taken to avoid a ventriculoperitoneal shunt if it is present. Careful incision site selection may also incorporate the right lower quadrant port into the lateral edge of the Pfannenstiel incision in order to minimize total incision length. Transperitoneal access is established and the abdomen insufflated to an age-appropriate pressure.

While there is no ideal bowel segment for augmentation cystoplasty, ileum is clearly the most common segment utilized due its compliance and minimal

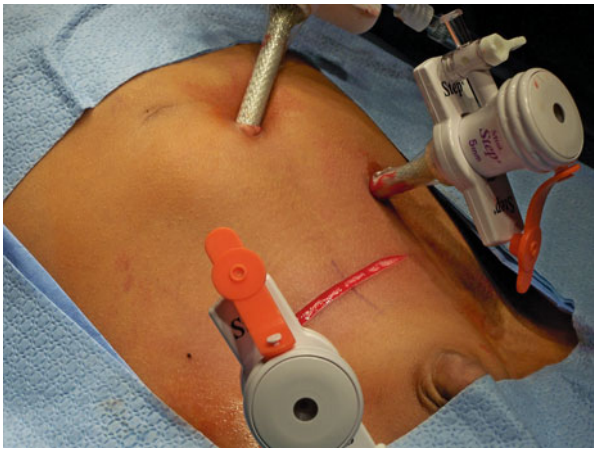

Fig. 16.1 Port placement for laparoscopic-assisted bladder augmentation using three ports

mucous production. The first step towards selecting an appropriate segment of ileum is identification of the appendix and ileocecal valve. Identifying these landmarks can be challenging in the presence of adhesions, commonly from a ventriculoperitoneal shunt in this population. If a shunt is present, then it is usually easy to move the shunt away from the site of dissection so as to minimize the risk of future infections.

The use of bowel graspers and bed positioning can help expose the appendix and cecum. Retracting the appendix anteriorly on stretch should expose the avascular line of Toldt and guide mobilization of the right colon. Electrocautery along the lateral edge of the right colon mobilizes the cecum and distal ileum in order to reach the pelvis. The appendix can be marked by leaving a grasper clamped to the distal tip.

While a Pfannenstiel incision allows for excellent exposure to the pelvis and bladder, identification of the appendix through this incision alone can be challenging. Prior laparoscopy eases identification and facilitates cephalad dissection for maximal mobility of the bowel into the pelvis. The distal 15–20 cm of ileum is spared in order to prevent steatorrhea and vitamin B12 deficiency. The remainder of the procedure should be conducted identically to a traditional open approach.

At the conclusion of the procedure, the right lower quadrant port site can be incorporated into the lateral edge of the Pfannenstiel incision, the umbilical incision is either buried within the umbilicus or used as a Mitrofanoff channel, and the 5 mm left lower quadrant incision may be used as the wound soaker exit. A suprapubic tube and wound soakers exit through the left lower quadrant (see Fig. 16.2).

Postoperative Management/Acute Complications

All patients following enterocystoplasty are initially kept nil by mouth. The use of nasogastric decompression is generally not necessary and may introduce an unnecessary aspiration risk, particularly in this patient population [8, 10]. Postoperative electrolytes should be checked to ensure appropriate fluid management. Continuous bladder

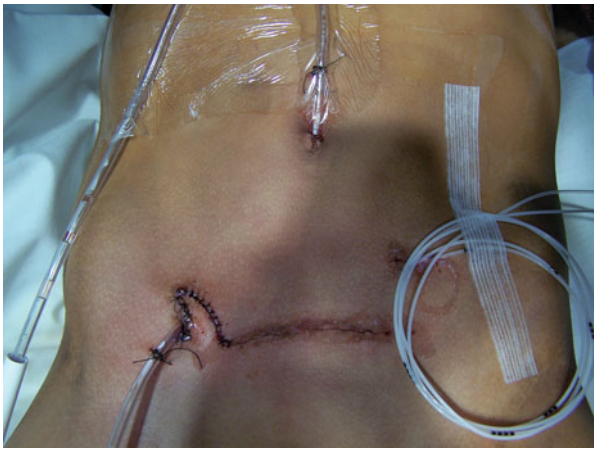

Fig. 16.2 Final appearance of closure and tube placement

drainage should be maintained in addition to periodic irrigation twice daily to avoid occlusion by blood clot or mucous production. Clamping of catheters can be commenced after 10 days, followed by intermittent catheterization, usually after 4 weeks.

Acute complications following augmentation cystoplasty include bleeding, infection, urinary leak, and metabolic abnormalities. Bowel obstruction may occur in approximately 5 % of patients following augmentation [1]. Laparoscopy adds minimal morbidity to these known complications of open augmentation. Any enterotomy should be recognized and may be addressed either laparoscopically or open. Port-site hernia is a rare potential morbidity.

Results/Late Complications

Ileocystoplasty is a reliable method to increase bladder capacity and decrease intravesical storage pressures with a less than 10 % need for additional augmentation work [11]. Bowel will continue to display peristalsis or mass contraction, but this should be minimized by detubularization. The native bladder should be widely opened to avoid stenosis of the anastomosis.

Bladder calculus is a common long-term complication ranging from 15 to 52 % of patients following augmentation [12, 13]. Bacteriuria may be an important risk factor for struvite stone formation. Techniques to reduce this complication include frequent and complete catheterization as well as routine bladder irrigations to avoid buildup of mucus as a nidus for stone formation.

Metabolic abnormalities include deficiencies of vitamin B12, vitamin D, folic acid, as well as hyperchloremic acidosis. Periodic laboratory evaluations are important to monitor these parameters chronically.

Bacteriuria is commonplace after augmentation, particularly when intermittent catheterization is required. Clearly, not all episodes of asymptomatic bacteriuria should be treated with antibiotics. Bacteriuria should be treated for UTI symptoms, which may include incontinence, pain, hematuria, fever, or foul-smelling urine.

Finally, patients undergoing augmentation cystoplasty should be made aware of an increased risk of tumor formation. The benefit and onset of surveillance cystoscopy are not known. Cystoscopy and CT scanning should be more strongly recommended following hematuria that is not associated with catheter trauma.

Author Remarks

Complete laparoscopic augmentation procedures have been successfully reported; however, the required technical skill has led to reported operative times ranging from 5 to 11 h [2, 3], and has not been widely adopted. A hybrid technique of initial laparoscopy followed by a Pfannenstiel approach offers a practical approach to utilizing the advantages of laparoscopy, minimizing postoperative discomfort, optimizing cosmesis, and continuing the technical advantages of traditional open reconstruction.

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Chapter 17
Robotic-Assisted Laparoscopic Ileocystoplasty: Our Technique

Pankaj P. Dangle, James Kearns, Dan Shen, and Mohan S. Gundeti

Abstract Augmentation ileocystoplasty for neurogenic bladder is a promising surgical option in patients with neurogenic bladder. The procedure has truly evolved since its first description in 1889 and has been a gold standard for treatment of neurogenic bladder.

Surgical approach has been modernized to facilitate the benefits of minimally invasive surgery via robotic laparoscopic approach. Laparoscopic reconstruction did not gain popularity due to the significant challenges of intracorporeal suturing. While robotic technique has been attempted, its initial attempts were a hybrid of both intra- and extracorporeal surgeries, with important steps being performed extracorporeally. We at our institute have adopted a total intracorporeal approach, and herein we share the tips and the tricks for successful completion of the procedure.

Keywords Neurogenic bladder • Augmentation cystoplasty • Robotic approach • Intracorporeal

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Introduction

Augmentation ileocystoplasty is a well-established management technique for neurogenic bladder that protects the upper urinary tract while allowing patients to achieve social continence [1–3].

Initial applications were focused on moderately complex surgeries, such as pyeloplasty, nephrectomy, and partial nephrectomy. As experience with the robot builds, a few centers of excellence have pushed the boundaries of robotic surgery even further by performing robotic bladder augmentation and appendicovesicostomy.

The initial case reports describing pediatric augmentation cystoplasty and appendicovesicostomy generated interest in greater application of robotics for these procedures [4–7]. The initial approach involved a hybrid of intracorporeal and extracorporeal surgery, with the most challenging steps performed extracorporeally. The idea was that extracorporeal reconstruction would produce better anastamoses [5]. Further experience and proof-of-principle porcine models demonstrated that intracorporeal reconstruction is feasible, allowing for true minimally invasive approaches to these highly complex surgeries. At the authors' institution, we routinely perform a completely intracorporeal robotic-assisted laparoscopic augmentation ileocystoplasty [8]. We will present our initial experience and outcomes later in this chapter.

History of Augmentation Cystoplasty, Evolution, and Advancement of Various Surgical Approaches

First described by von Mikulicz in 1889 [9], augmentation ileocystoplasty was later popularized by Couvelaire [10] in the 1950s. Various techniques using different segments of bowel, including the stomach, jejunum, and colon, have been described [11]. Other natural grafts, including the omentum, peritoneum, lyophilized dura mater, skin, and pericardium, have also been used but with less success and more complications [12]. Atala et al. have reported on their use of tissue-engineered autologous bladder transplantation, and this approach is still in the experimental phase and not ready for widespread adoption [13, 14]. Synthetic materials have been tried and abandoned due to myriad complications including stone formation, recurrent urinary tract infection, fibrosis, and contracture [15, 16].

The ileum remains the preferred bowel segment for augmentation cystoplasty based on published outcome studies. The open surgical approach remains the gold standard for augmentation cystoplasty at this time [17].

The extensive amount of reconstructive work required for augmentation cystoplasty has been the limiting factor in approaching this surgery in a minimally invasive fashion. Complex steps include selection of an appropriate bowel segment, mobilization and reconfiguration of the bowel, and the significant amount of suturing necessary for a successful operation. For these reasons, open

ileocystoplasty has been the gold standard approach. Laparoscopic enterocystoplasty was first described in 2000 [18], initially involving extracorporeal bowel anastomosis but quickly evolving to a completely intracorporeal reconstruction [19]. This technique was then applied to the pediatric population by Lorenzo et al. [20]. Complete laparoscopic reconstruction has not been widely adopted due to the advanced laparoscopic skills required in addition to the very steep learning curves associated with these procedures. However, the maturation of robotic technology has brought about a paradigm shift toward minimally invasive surgery for complex reconstruction. While advancing technology makes a minimally invasive approach to reconstruction easier, surgeon experience remains critical to understanding the pathophysiology of this disease. At our institution, we prefer a complete hand-sewn intracorporeal bowel anastomosis over a stapled anastomosis [21].

Preoperative Evaluation

A comprehensive preoperative evaluation must be undertaken for all patients prior to bladder augmentation. Urodynamic studies are performed to confirm the diagnosis of neurogenic bladder, followed by radioisotope renal scanning to measure both renal function and scarring. A multidisciplinary meeting with the pediatric urologist, midlevel providers (nurse practitioner), and the patient's family is conducted. All options, surgical and nonsurgical, must be presented, and the necessity for lifelong follow-up and compliance with the treatment plan should be underscored. At our institution, the pediatric urology nurse practitioner meets with the patients and their families after the decision to proceed with surgery with emphasis on the need for lifelong self-catheterization. All patients are shown a brief video of the procedure and discussion regarding the site of stoma placement at the umbilicus versus right iliac fossa depending on the patient's dexterity and ambulatory status for those requiring concomitant catheterizable channels.

We also routinely obtain preoperative neurosurgical consultation to address existing ventriculoperitoneal shunts and the rare occurrence of secondary tethered cord syndrome that occurs postoperatively due to prolonged lithotomy positioning.

Perioperative antibiotics include cephalosporins, metronidazole, and gentamicin, which are given preoperatively in the operating room and then continued for 24–48 h depending on the preoperative urine cultures. Vancomycin is added when the patient has a ventriculoperitoneal shunt. In accordance with recent observational data [20], we do not routinely give preoperative bowel preparation. In 162 cystoplasties performed, the author reported postoperative complications in 9.87 %: urinary (2.4 %) and only three patients with wound infection (1.85 %). The authors concluded that mechanical bowel preparation can be omitted in children that require augmentation cystoplasty without an increased risk of infectious or anastomotic complications [22].

Indications for Surgery

The goal of bladder augmentation is to achieve social continence while preserving renal function. Patients should have previously failed conservative management for urinary incontinence and/or have an impending risk of upper urinary tract damage. Previous intra-abdominal surgeries present a relative contraindication due to the possibility of adhesions. Abnormalities of the axial skeleton (e.g., severe kyphoscoliosis) may preclude the ability to properly position the patient or achieve pneumoperitoneum.

Our Surgical Technique

(See accompanying Video 17.1.)

Preferred Patient Positioning

Patient positioning is critical for the success of robotic procedures, and each procedure requires different positioning to achieve adequate exposure. In addition, pediatric patients are a risk for position-related complications such as pressure injuries and nerve palsies.

For robotic ileocystoplasty, we position patients in the low lithotomy position with 30° of Trendelenburg. All upper and lower extremity pressure points are padded with thin foam. Thin foam is also used on the chest to avoid creating pressure points when securing the patient to the bed. We also use foam padding to protect the face from incidental damage caused by the camera arm.

We place the Foley catheter after sterile preparation to allow for intraoperative manipulation and bladder filling. All patients have a warm-air heating blanket applied for temperature control, and an orogastric tube is placed for the duration of the surgery.

The robotic cart is brought into position between the patient's legs, taking care to avoid any injury to the patient.

Figure 17.1 show the operating room setup for renal and pelvic procedures, respectively.

Prevention of Deep Venous Thrombosis

Deep venous thrombosis presents a significant risk in this patient population due to the long operating times associated with robotic ileocystoplasty, during which the

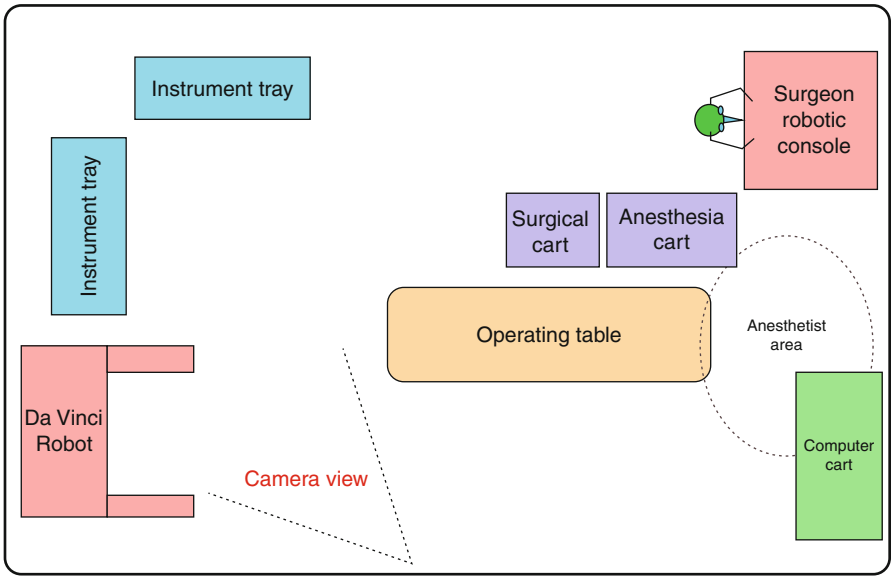

Fig. 17.1 Operating room setup for pelvic procedures (e.g., cystoplasty)

patient is in lithotomy position. In addition, these patients tend to have limited mobility secondary to their underlying medical conditions. At the authors' institution, sequential pneumatic compression stockings are placed preoperatively and continued throughout surgery and the remainder of the hospitalization.

All patients should be screened for nutritional abnormality and hematologic disorders, including protein C and S deficiencies. High-risk patients receive subcutaneous heparin prophylaxis beginning prior to induction of anesthesia and continuing through the remainder of the hospital stay.

Surgical Steps

1. Port placement – Proper port placement is critical for the success of any robotic procedure. The primary camera port is placed using an open Hasson technique 12 cm from the superior edge of the pubis, preferably at or below the umbilicus. If the distance to the umbilicus is less than 9 cm, the port is placed superior to the umbilicus (Fig. 17.2). Secondary (working) ports are marked and placed after pneumoperitoneum is achieved. We place two 8 mm ports in line with the camera port, each 6–8 cm lateral to the camera port. The port for the 4th arm (8 mm) is placed in the left iliac fossa at the anterior axillary line. When placing the stoma in the right iliac fossa, we place an additional 12 mm port in the right iliac

fossa at the midaxillary line. This serves as the stoma site at the end of the procedure. The extra 12 mm port is used for application of LAPRA-TY clips and passing large needles.

We currently use a 12 mm balloon port for the camera because their short intracorporeal length allows for increased intra-abdominal working space and because it is less likely to become dislodged during the surgery. We use a heated coil gas tube for insufflation to prevent the lens from fogging. We set pressure to 15 mmHg for trocar insertion and then drop the pressure to 10–12 mmHg with a flow of 2 L/min. We use a 0° lens for the initial assessment and bowel anastomosis and a 30° lens for the remainder of the procedure.

2. Primary assessment – We start with an initial intraperitoneal examination of the small bowel and bladder, paying particular attention to length and vascularity. In patients with a ventriculoperitoneal shunt, we place the shunt in an Endo Catch bag to avoid damage or contamination during the procedure.
3. Bowel isolation and anastomosis – We identify the ileocecal junction and then mark a 20 cm segment of the ileum 15 cm proximal to the ileocecal valve using a premeasured 10 cm silk suture. We place percutaneous stay sutures at both the proximal and distal ends with 3-0 silk sutures, taking care to maintain good vascular supply to the mesentery. Percutaneous suspension allows for improved visualization of the mesentery, bowel transection, and anastomosis. Prior to anastomosis, we place traction sutures on the mesenteric borders. We then perform a single-layer seromuscular end-to-end anastomosis with 4-0 monofilament or polyglycolic acid suture (Fig. 17.3).

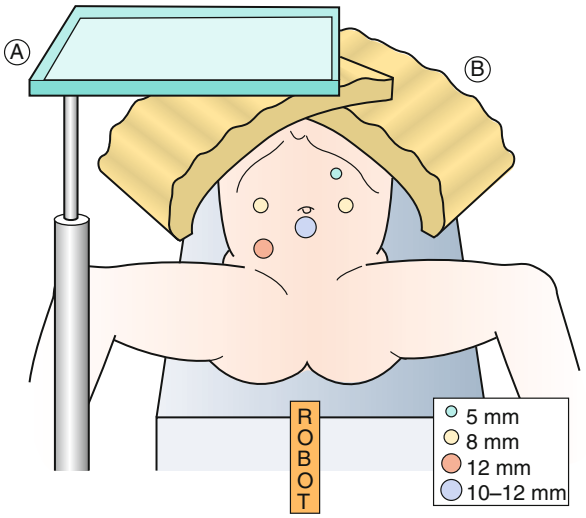

Fig. 17.2 Patient position and port placement for augmentation cystoplasty. *A* Mayo stand, *B* Foam pad to cover chest. (Reprinted with permission from Gundeti [24])

4. Vesicostomy, detubularization, and ileovesical anastomosis – We distend the bladder with saline through the previously placed Foley catheter. After the bladder is distended, a transverse cystotomy is made in the coronal plane extending to the bladder side walls up to the ureteral insertion, taking precaution not to be in close proximity. Prior to detubularization of the small bowel, we place a suction cannula in the lumen to assist with alignment and identification of the antimesenteric border. The fourth arm helps to maintain traction of the ileal segment during detubularization. Pre-placed dyed and undyed sutures are used to assist with orientation of the ileal patch and to complete the ileocystoplasty anastomosis. The posterior anastomosis is performed first, followed by the anterior anastomosis using 3-0 polyglycolic acid sutures. Unmatched lengths of the ileocystoplasty anastomosis are overcome with

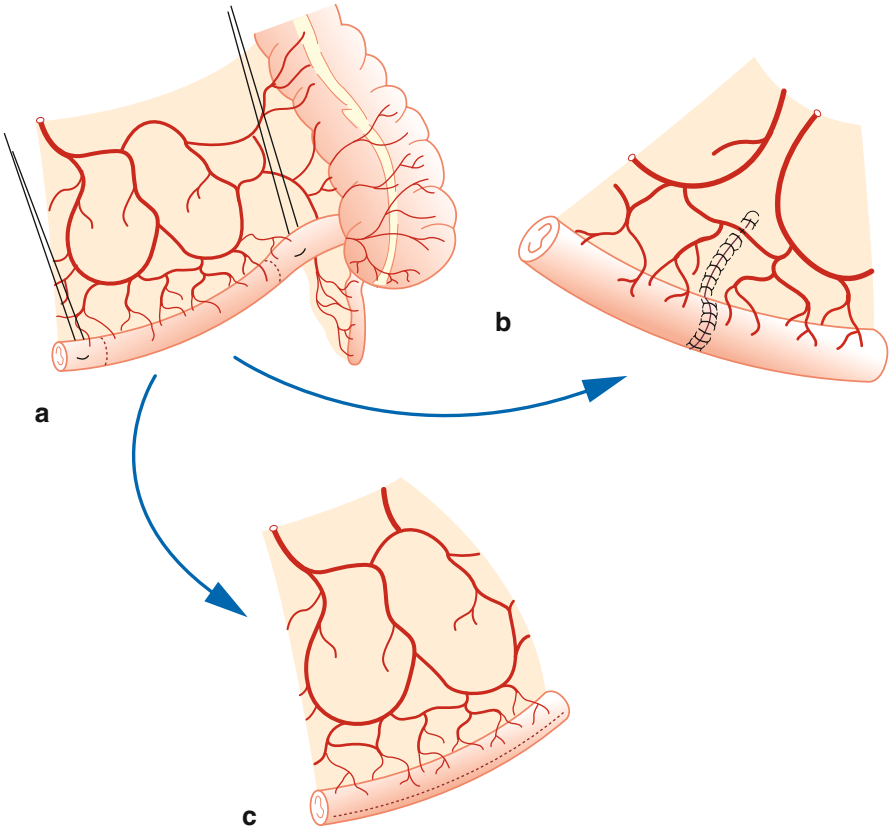

Fig. 17.3 Bowel isolation and anastomosis. (**a**) Bowel isolation. (**b**) Anastomosis of the bowel and (**c**) isolated bowel patch for augmentation system cystoplasty (Reprinted with permission from Gundeti [24])

imbricating sutures. We place a suprapubic catheter after completion of the posterior anastomosis. After completion of the anastomosis, its integrity is tested by instilling saline through the suprapubic catheter (Figs. 17.4 and 17.5).

5. If a simultaneous catheterizable channel is to be performed, appendix is harvested first, and then after bowel work before the ileovesical anastomosis, the appendix is reimplanted on the posterior wall.
6. In cases with simultaneous bladder neck surgery, this is undertaken before the ileovesical anastomosis as well.

Comments

Our experience shows that patients undergo an uncomplicated postoperative course. Pain is generally well controlled with acetaminophen and ibuprofen, with morphine only being prescribed as needed. Most patients resume a general diet within 24 h of surgery. The Jackson-Pratt drain is generally removed on postoperative day 3. We remove the urethral catheter on postoperative day 5 and maintain the suprapubic catheter to gravity drainage for 4 weeks. Patients start self-catheterization, and once established, then the suprapubic catheter is removed.

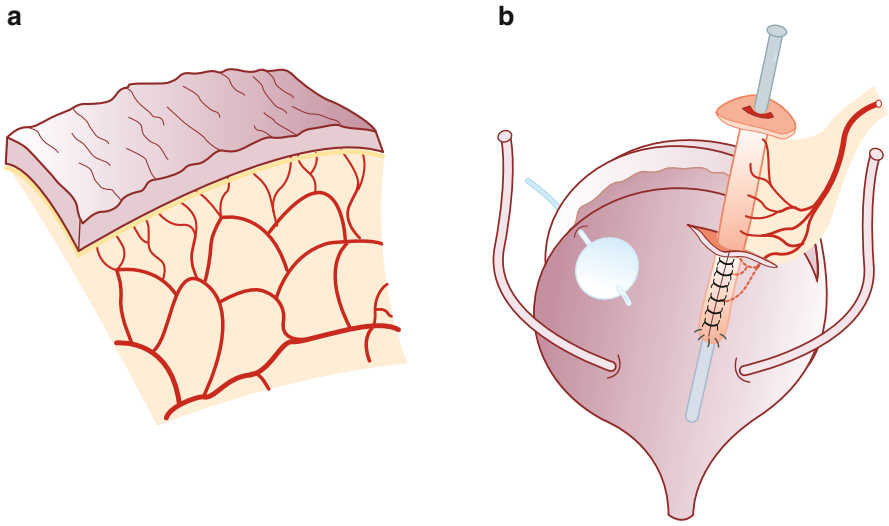

Fig. 17.4 Detubularization and vesicostomy. (**a**) Detubularization of the isolated bowel segment. (**b**) Vesicostomy (Reprinted with permission from Gundeti [24])

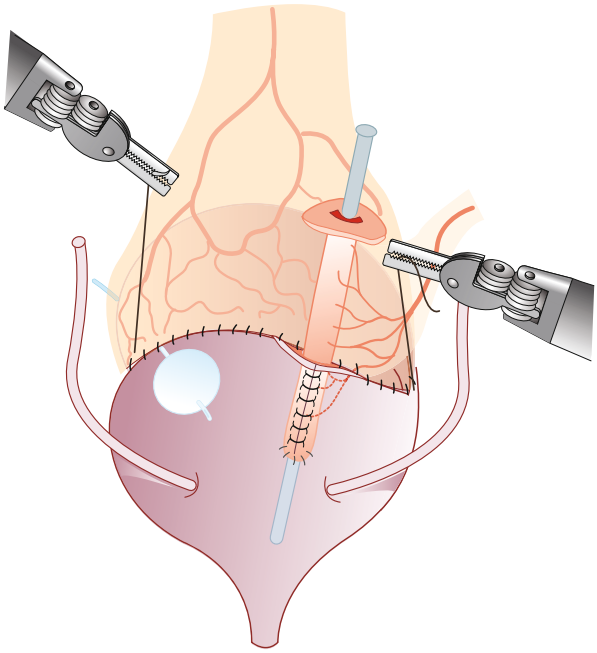

Fig. 17.5 Completed ileovesical anastomosis and appendicovesicostomy (Reprinted with permission from Gundeti [24])

Conclusion

Robotic technology has created a paradigm shift in surgery, with greatly increased emphasis on minimally invasive techniques. While initially applied to the adult population, robotic surgery is being increasingly applied to pediatric patients [23]. This tool allows for the performance of highly complex surgeries in a minimally invasive manner. Multiple centers have demonstrated that robotic ileocystoplasty is feasible. However, these procedures require a great deal of skill and experience and should be avoided by the pediatric urologist who is still in the initial phase of his or her career. Appropriate training and proctoring on both animal models and eventually human patients allows for successful and safe navigation of the learning curve. With experience, lengthy operative times will decrease. Furthermore, future refinements to robotic technology will likely provide more equipment targeted to the pediatric population. With these enhancements, robotic- assisted laparoscopic surgery will lead to widespread application of minimally invasive surgery in even the most complex of pediatric urologic procedures.

Robotic surgery, particularly for complex reconstruction such as augmentation cystoplasty and catheterizable channel, has a significant learning curve. Though the early results are promising, there is a need for randomized study comparing with the open gold standard approach.

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Chapter 18
Impalpable Testis

Duncan T. Wilcox

Abstract An undescended testis is a common congenital anomaly; in the majority of patients, the testis is palpable, and an open procedure is indicated; however, in about 20 % of patients, the testis in not palpable. When the testis is not palpable, it is frequently necessary to perform laparoscopy: firstly, as an investigation to ensure the presence of a testis and identify its location and secondly, as a therapeutic maneuver to bring the testicle into the correct location in the scrotum. The testis can be brought down either as a single procedure or as a two-stage procedure. In this chapter the techniques of these procedures are described along with the outcomes and complications.

Keywords Undescended testis • Laparoscopy • Testicular nubbin • Orchiopexy • Orchidopexy

Undescended testis is a common congenital anomaly occurring in approximately 1 % of male infants. In approximately 20 % of patients with an undescended testicle, the testis is not palpable [1]. The management of a child with a palpable testis is not controversial, but management of an infant with an impalpable testis can generate considerable clinical debate. Despite improvements in cross-sectional imaging, the most accurate evaluation of the undescended testicle is by a diagnostic laparoscopy [2, 3]. Since the laparoscopic orchidopexy was first described by Jordan in 1992, a therapeutic procedure can be performed at the same anesthetic [4].

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Prior to embarking on a diagnostic laparoscopy, it is important to ensure that the patient has an isolated undescended testicle and is not suffering from an intersex disorder [5]. Once the child is under general anesthesia, it is also vital to reexamine the patient, as previously undetected testicles can become palpable, thereby avoiding the need for laparoscopy [6]. Or a testicular nubbin can be palpated in the scrotum and in these patients, exploration of the scrotum first can frequently avoid laparoscopy also [7]. In those patients who still have an impalpable testicle, it is reasonable to proceed with laparoscopy [8].

Indications and Contraindications

A diagnostic laparoscopy is indicated if testes are impalpable and no testicular nubbin is felt despite careful examination under anesthesia.

Contraindications include bleeding disorders and children who have undergone previous abdominal surgery. In these patients, particular attention should be paid to the placement of the ports.

Preoperative Preparation

No specific preoperative preparation is necessary.

Patient Position

The patient is placed supine on the operating table. Once the ports are in position, the patient is then put head down to clear the small bowel from the operative field. The positions of the anesthetist (A), surgeon (S), camera holder (C), scrub nurse (N), and audiovisual equipment are shown in Fig. 18.1.

Port Positioning

The camera port is placed either in a supra- or infraumbilical skin crease, using the open Hassan technique. Either a 5 or a 3 mm port is used. If a testicle is identified, then two further ports are placed under direct vision.

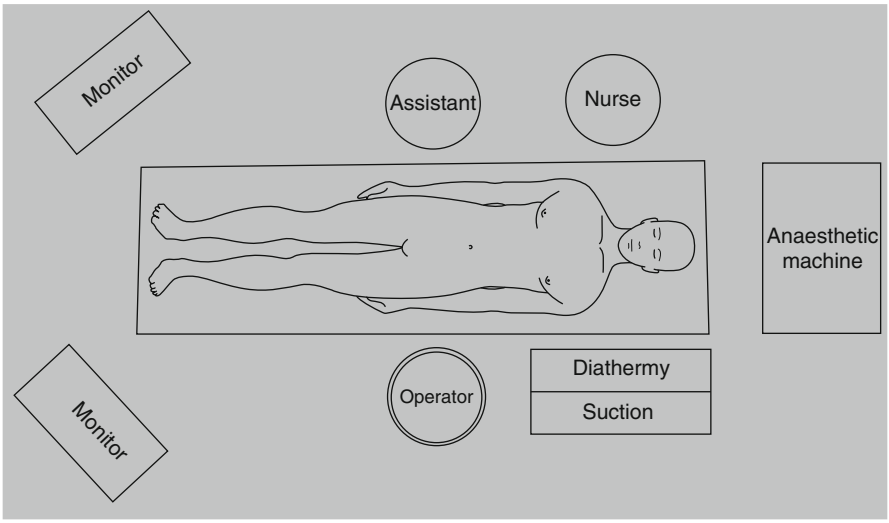

Fig. 18.1 Diagram showing the positioning of the staff and equipment around the operating table

Operative Technique

A pneumoperitoneum is created using CO_2 gas, with a flow rate of 1–2 L/min and a pressure of 10–12 mm of mercury. A 30° laparoscope is usually used to aid visualization of the peritoneal cavity.

Once inside the peritoneal cavity, the normal side is examined first to reconfirm normal anatomy. The first landmark is the median umbilical fold (obliterated umbilical artery) on the anterior wall of the bladder. The vas deferens should cross over it from medial to lateral, running toward the internal ring. This is joined by the testicular vessels, which run parallel to the iliac vessels (see accompanying Video 18.1) (Fig. 18.2).

The findings that can be seen at diagnostic laparoscopy include:

1. Normal vas and vessels entering the canal with or without a patent process vaginalis. Occasionally a testicle can be seen peeping in from the internal ring (see accompanying Video 18.1).
2. Intra-abdominal testis with normal vas and vessels with adequate mobility. This is usually assessed by seeing if the testis can reach the opposite internal ring (see accompanying Video 18.2).
3. Intra-abdominal testis with short vessels and normal vas deferens (see accompanying Video 18.3).
4. Vessels that become atretic before entering the internal ring. This represents an absent testicle. This is only true if the vessels can be seen and become atretic, not if the vas is not visualized alone (see accompanying Video 18.4).

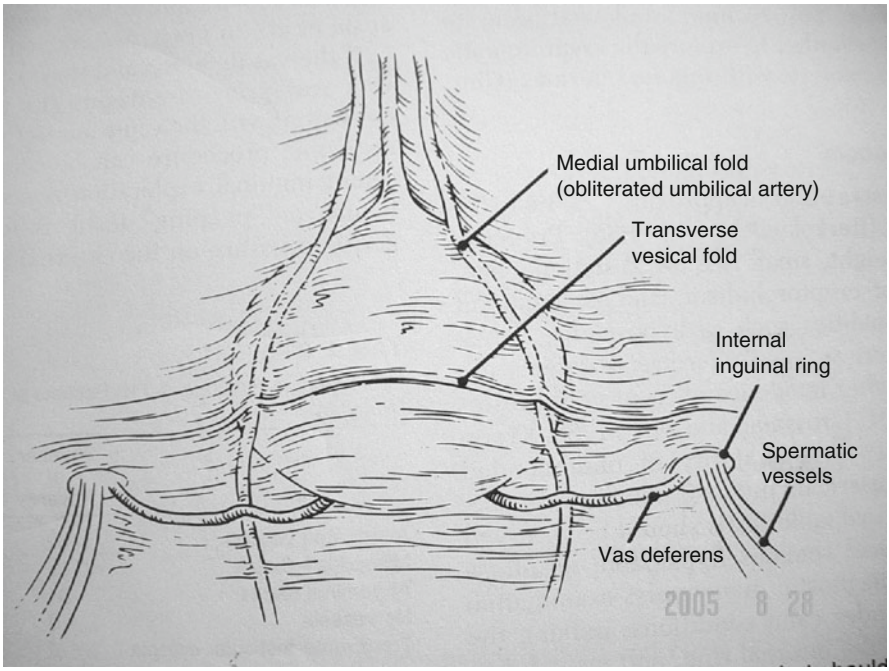

Fig. 18.2 The normal anatomy of the internal ring

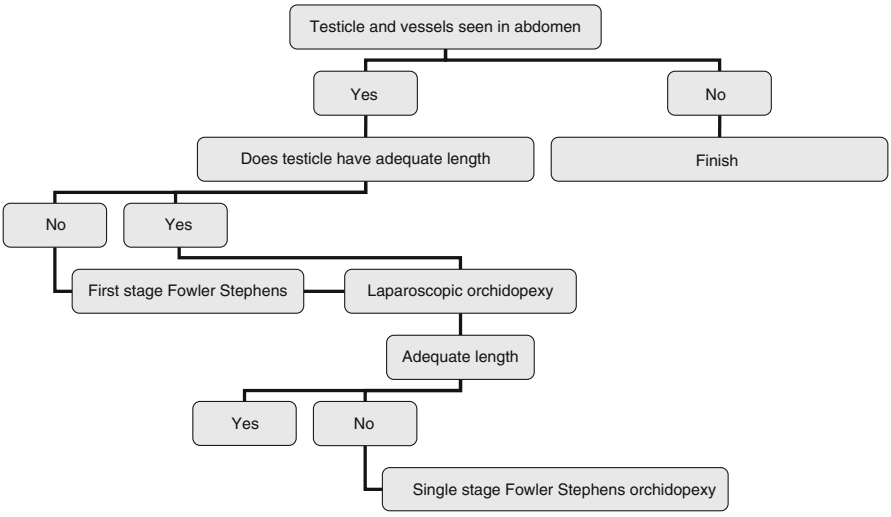

Fig. 18.3 Algorithm for the management of a patient with an intra-abdominal testicle

Once the diagnostic laparoscopy is performed, there are three treatment options if a testicle is seen: (1) a single-stage orchidopexy, (2) the first stage of a Fowler Stephens orchidopexy, or (3) a single-stage Fowler Stephens orchidopexy. Figure 18.3 proposes a management algorithm.

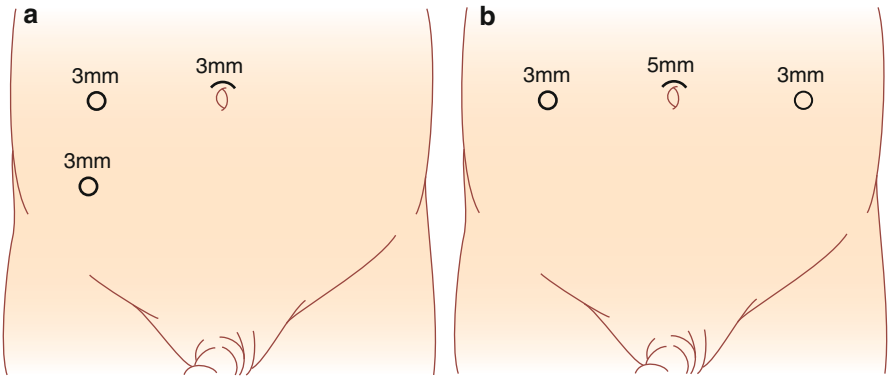

Fig. 18.4 Port site position for a unilateral (**a**) or bilateral orchidopexy (**b**)

Single-Stage Laparoscopic Orchidopexy

Indication

An indication for this procedure is intra-abdominal or peeping testis with good vas and vessels that appear to have adequate length.

Port Position

Following the placement of the camera port, two working ports are placed with local anesthetic under direct vision. The position of ports for a standard orchidopexy is shown in Fig. 18.4a, b).

Operative Technique

The peritoneum is incised lateral to the testicular vessels (position A) and continued to the internal ring. The gubernaculum is divided, and the incision on the peritoneum is extended running parallel with the vas deferens. Care is necessary to ensure that the vas is not damaged. This maneuver is aided by grasping the gubernaculum that is still attached to the testicle and bringing it across to the contralateral internal ring. When this is completed, the peritoneum is incised over the testicular vessels and continued to join the incision at position A. This incision can then be continued down into the pelvis running parallel to the vas deferens. This approach allows the maximum mobilization of the testicle without ligating the vessels.

A subdartos pouch is created, and a grasping forceps or a transscrotal port is placed into the peritoneum either through the inguinal ring or, if there is insufficient

length, medial to the inferior epigastric vessels. The testis is then grasped and brought in to the subdartos pouch. If at this point there is insufficient length, then further dissection of the peritoneum can be performed. Occasionally removing the pneumoperitoneum allows for sufficient length (see accompanying Video 18.5).

Fowler Stephens First-Stage Laparoscopic Orchidopexy

Indication

The indication for this procedure is intra-abdominal testis with short vessels.

Port Placement

Port placement is the same as for the single-stage orchidopexy discussed earlier.

Operative Technique

The testicular vessels are identified. Then, the peritoneum is carefully dissected off the vessels 1–2 cm from the testicle. Care is taken not to damage the peritoneal tissue between the vas and vessels, as this may be source of the future collateral blood supply. The vessels are then obliterated with a clip applicator, ligation, or diathermy according to surgeon preference (see accompanying Video 18.6).

Fowler Stephens Second-Stage Laparoscopic Orchidopexy

Indication

The patient should have had a first-stage Fowler Stephens orchidopexy. The second stage is usually performed 6 months after the initial procedure.

Port Placement

The same as described for the first-stage orchidopexy.

Operative Technique

The obliterated vessels are first divided. The peritoneum is incised lateral to the vessels and testis. This is continued to the internal ring, where the gubernaculum is divided. While still attached to the testis, the gubernaculum is then grasped and pulled toward the contralateral internal ring. The peritoneum is then incised parallel to the vas deferens on both the distal and proximal sides, ensuring a wide rectangle of peritoneum. The dissection of the rectangle of peritoneum is continued down into the bladder until sufficient length is achieved. The testis is then placed in a subdartos pouch as described previously (see accompanying Video 18.7).

Single-Stage Fowler Stephens Orchidopexy

Indication

The indication is inability to complete a laparoscopic orchidopexy without ligating the testicular vessels.

Port Placement

The port placement is the same as described earlier.

Operative Technique

Both the first and second stages of the Fowler Stephens orchidopexy are performed under a single anesthetic.

Closure

Following completion of the laparoscopic procedure, insufflation pressure is reduced, and any obvious bleeding is visualized and stopped. The ports are removed under direct vision. The port sites are sutured (midline fascial and then skin) to prevent wound herniation.

Complications

The most common complication is that the testicle becomes ischemic. This depends on the original position of the testicle and the type of surgical procedure performed. The testicle can also retract out of the scrotum toward the inguinal canal [6].

Bowel injury can occur either at the time of port insertion or from diathermy injury. Both of these are extremely rare.

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Chapter 19
Laparoscopic Varicocelectomy

Joseph M. Gleason and Martin A. Koyle

Abstract The adolescent varicocele remains a controversial issue in pediatric urology. In our institution, the indications for intervention are primarily the findings of a varicocele with ipsilateral testicular hypotrophy and less commonly for symptoms. Therapeutically, the patient and his family are counselled in depth regarding the conflicting data surrounding varicoceles and their management and then offered the options of surveillance (knowing that fertility potential cannot be reliably measured in this age group), radiologic embolization, or open surgical correction using a high Palomo technique or a microscopic subinguinal method. The majority of this author's patients, however, choose the laparoscopic approach to the Palomo high ligation of the spermatic vessels. The primary reasons why patients and families make this choice are due to its high success, minimal morbidity, virtually no scars, and, most importantly, because it allows rapid return to full activity. Success rates are excellent (>99 %) and recurrence rates are very low. De novo ipsilateral hydrocele formation is a potential complication that may require further intervention and must be disclosed during preoperative counselling but, in long-term follow-up, has only been necessary in 2–3 % of adolescents undergoing this technique. Testicular atrophy or loss has not occurred in our hands.

Keywords Varicocele • Varicocelectomy • Laparoscopy • Testicular hypotrophy • Palomo

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Introduction

Varicocele is defined as tortuous and dilated veins of the pampiniform plexus surrounding the testis. Like varicose veins elsewhere in the body, they are caused by incompetent venous valves, which usually serve to protect the spermatic veins from the hydrostatic pressures imposed upon them prior to draining into the larger veins. The left spermatic vein drains into the left renal vein perpendicularly, whereas the right spermatic vein drains directly into the vena cava at a more acute angle, leading to the vast majority of varicoceles being seen on the left. Retroperitoneal processes (i.e., tumors, retroperitoneal fibrosis, "nutcracker syndrome") can be the etiology of secondary varicoceles in a small minority of cases but should always be considered, especially with right-sided varicoceles. Bilateral varicoceles, many of which are subclinical, can often be discovered when ultrasonography is employed. Varicoceles have long been associated with male factor infertility, and varicoceles allow abdominal temperature blood to accumulate in the scrotum leading to increased temperature in the scrotum/testis on the affected side, ultimately impairing spermatogenesis. In children, most will be detected on routine physical or self examination, but a small subset will present with testicular or scrotal pain. Since children and adolescents are not being evaluated for infertility, patients referred to a pediatric urologist are much more likely to harbor high-grade (Grade III) varicoceles, rather than moderate less conspicuous varicoceles (Grade II) or subclinical (Grade I) varicoceles.

The management of asymptomatic varicoceles in children remains a topic of controversy. With an incidence in 15 % of the adult male population, it remains a common surgically correctable urologic problem [1]. Recent evidence suggests they may be more prevalent in adolescents who are taller and heavier than age-matched controls [2]. However, most men with varicoceles are asymptomatic and fertile, as determined by paternity [3]. Therefore, the question of who needs to be operated upon remains at the forefront of discussions among pediatric urologists. Criteria used to make assessment have included testicular size discrepancy, varicocele size or unsightliness, symptoms, and semen parameters. Kolon recently described the management algorithm at the Children's Hospital of Philadelphia, where children are followed annually with examinations using an orchidometer until Tanner stage 5 is reached, at which point semen analyses are offered. Surgical correction is reserved for those with low total testicular volume or semen parameters and rarely for symptoms [4]. Not much data exists on the impact of varicocele ligation on semen parameters in younger patients nor on ultimate fertility and paternity. Pajovic recently reported their findings on semen parameters following varicocelectomy and claimed that testicular volume, sperm counts, abnormal forms, viability, and semen pH were all significantly improved 3 months following laparoscopic varicocelectomy in 23 men with varicoceles and abnormal parameters preoperatively [5]. Others have suggested improvements in spermatogenesis, Sertoli and Leydig cell function following varicocelectomy [6–8]. Kozakowski et al. also suggested that all of the adolescents with peak retrograde flow >38 cm/s

in addition to testicular asymmetry >20 % showed progressive asymmetry on follow-up ultrasounds if not operated upon, recommending these be corrected on initial presentation [9]. In our experience, many families choose repair because of the uncertainty long term regarding their son, even with equal testes size and normal spermiogram.

Palomo initially described an open retroperitoneal approach to varicocele ligation in 1949 with a muscle splitting incision and ligation of the entire vascular package medial to the ureter [10]. No attempt to preserve lymphatics or the spermatic artery was made. This approach can be reproduced laparoscopically with minimal morbidity, faster operating times, and immediate return to full activities. No strong data support sparing the artery and lymphatics. Certainly hypothetically preserving the lymphatics in an attempt to prevent secondary hydroceles seems logical; in our hands, the risk of hydrocele requiring surgery has been <3 %. Moreover, even with mass ligation of the cord, no testes have been lost in our experience, so again we follow the initial Palomo technique and make no attempt to identify the artery either. In addition, a laparoscopic approach allows for quick and easy assessment of the contralateral side and is safe to perform, even after ipsilateral inguinal surgery [11]. Although the veins can be interrupted in many ways, we have used a bipolar sealing device, both to dissect and to seal the vessels, and do not routinely divide the vessels after application of the instrument. This also allows us to avoid placing any laparoscopic ports, other than the umbilical site where the scope and camera are placed. Herein, that technique is described in detail.

Indications for Intervention of Known Varicocele

- Informed consent from both the patient (if of appropriate age) and parent(s)
- Younger children with relative testicular hypotrophy (>20 % volume loss compared to the contralateral testis)
- Older children with abnormal semen parameters (data lacking)
- Pain or discomfort of the ipsilateral testis (uncommon)
- Large and unsightly hemiscrotum causing psychological distress or anxiety (most common!)

Contraindications

- Hostile abdomen from previous surgery, precluding safe laparoscopic access (rare and has yet to occur in our practice)

Surgical Technique

Preoperative Preparation

- Have the patient void on call to the operating room
- No shaving of hair, as we prefer to make the suprapubic “working puncture” through pubic hair (if present) to conceal the scarMinimal Equipment Needed
- Scalpel

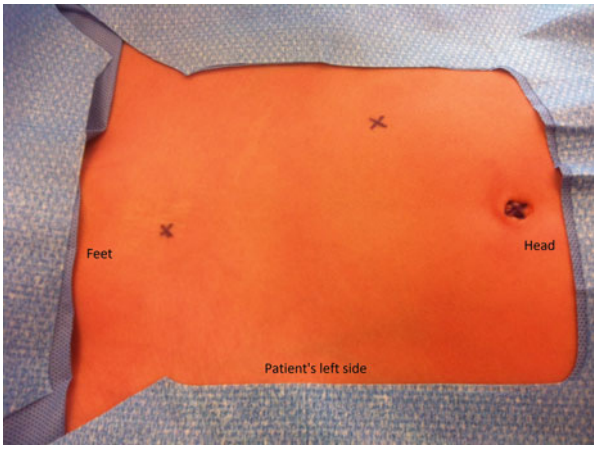

Fig. 19.1 Abdominal skin marking for instrument placement

- A single 3 or 5 mm trocar and insufflation tubing (umbilical port)
- 3 or 5 mm laparoscope with a 30° lens and light source
- Video tower with insufflation device
- 3 or 5 mm laparoscopic Maryland grasper (right lower quadrant puncture site)
- 5 mm laparoscopic bipolar vessel-sealing device (LigaSure, Thunderbeat, etc.) (suprapubic puncture site)
- A single suture (absorbable 3-0 or 4-0 of choice) with needle driver (to close umbilicus only)
- Local anesthetic
- Skin glue (Dermabond/cyanoacrylate) (for all incisions and puncture sites)

Laparoscopic varicocele ligation thus requires a minimal amount of instrumentation. Although a 3 or 5 mm trocar is used for the camera, the other instruments are placed through small "stab" incisions. The patient is asked to void on call to the operating room (avoiding the need for urethral catheterization) and is placed supine and general anesthesia is induced. No antibiotic prophylaxis is administered. Because the operation takes <15 min in most cases, many anesthesiologists are comfortable utilizing a laryngeal mask airway. That being said, the majority prefer to intubate due to the potential physiological consequences of pneumoperitoneum.

After prepping and draping in a standard fashion, the instrument entry sites are marked (Fig. 19.1). Pneumoperitoneum is achieved in a standard manner via an umbilical 3 or 5 mm trocar. Laparoscopic guidance is used to allow for direct visualization of placement of local anesthetic and to confirm safe locations for the stab incisions (Fig. 19.2). The Maryland dissector is then passed directly through the right lower quadrant stab incision under direct visualization (Fig. 19.3). A laparoscopic bipolar device is similarly passed through another stab incision just above the pubis in the midline.

Once all instruments are inserted satisfactorily, the left spermatic vessels are identified, and a site for incision of the posterior peritoneum above the spermatic vessels is identified as far cephalad from the internal ring as possible to avoid injury

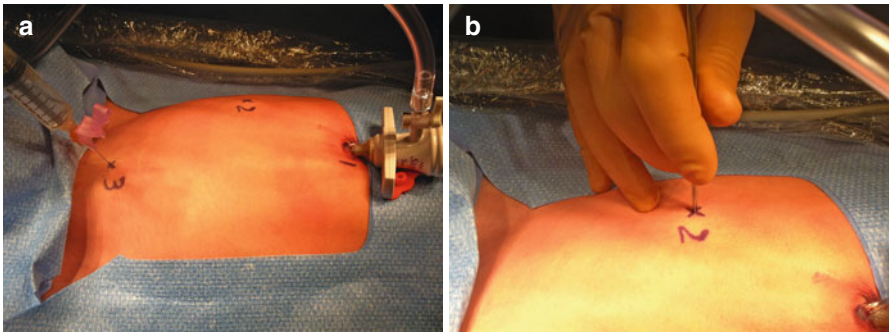

Fig. 19.2 (**a**, **b**) Local anesthetic and stab incisions made under direct visualization after placement of umbilical trocar

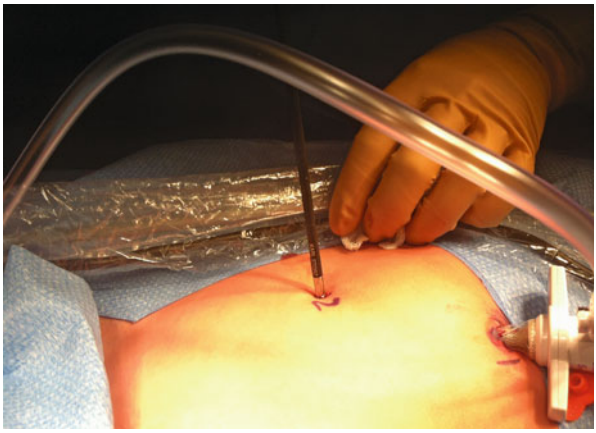

Fig. 19.3 Maryland dissector and bipolar device passed directly through stab incisions

to the vas deferens and collateral blood supply from the deferential vessels (Fig. 19.4). Trendelenburg positioning is often helpful during this step. Occasionally there are adhesions, especially of the sigmoid in this area. They can usually be lysed with the Maryland and bipolar device, and rarely will another working port or other instrumentation be required. Still the surgeon should be prepared for any eventuality, especially in a patient with prior abdominal, pelvic, or inguinal surgery.

The left-handed Maryland dissector is used to grasp the posterior peritoneum overlying the spermatic vessels, and the right-handed bipolar device pierces through the peritoneum, creating a window through which the vessels can be dissected free and isolated (Fig. 19.5). Once this maneuver has been accomplished, the vessels are grasped completely with the Maryland, and the bipolar is used to create a window behind the vessels, and the window is extending cephalad and caudad bluntly until an adequate area is visible for ligation. No attempt is made to separate the artery from the veins or to identify lymphatics as noted above (Fig. 19.6).

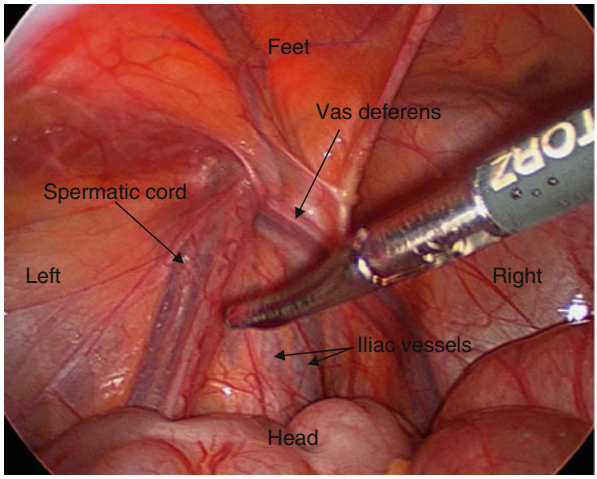

Fig. 19.4 Anatomy of relevant structures

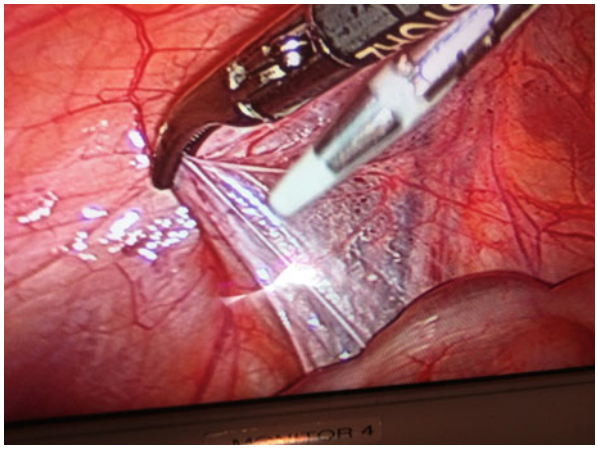

Fig. 19.5 Creation of peritoneal window

The bipolar device is applied to the entire vascular package 2–3 times to completely seal all vessels (Fig. 19.7). Intermittent traction on the ipsilateral testis can be applied to identify any additional vessels missed initially. The vessels are not routinely divided. Final inspection confirms no additional venous collaterals are present, hemostasis is achieved, the vas deferens and deferential vessels are undisturbed, and no overt complications have occurred (Fig. 19.8).

The abdomen is desufflated, and all instruments and the trocar are removed. A single 3-0 or 4-0 absorbable suture is used to close the umbilical fascia in a figure of eight fashion, to prevent herniation. No suture closure of the stab incisions is necessary. Additional local anesthetic is infiltrated, and the skin at the incision sites are all reapproximated with skin glue. Ketorolac 0.5 mg/kg IV is administered in the operating room, and the patient is discharged the same day with minimal oral analgesic requirements (NSAIDs and acetaminophen). We do not routinely

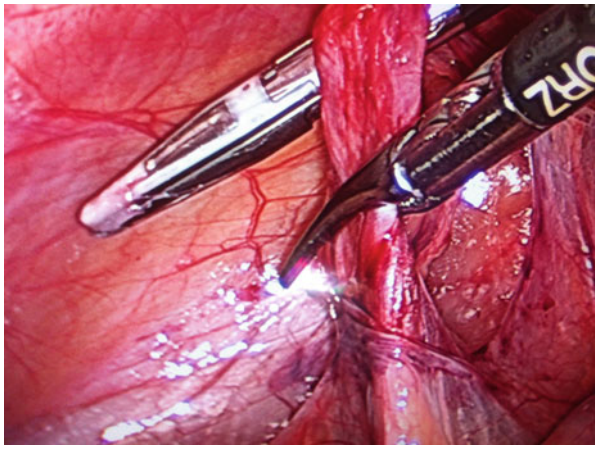

Fig. 19.6 Isolation of the spermatic cord using the bipolar device as dissector while grasping the cord with the Maryland dissector

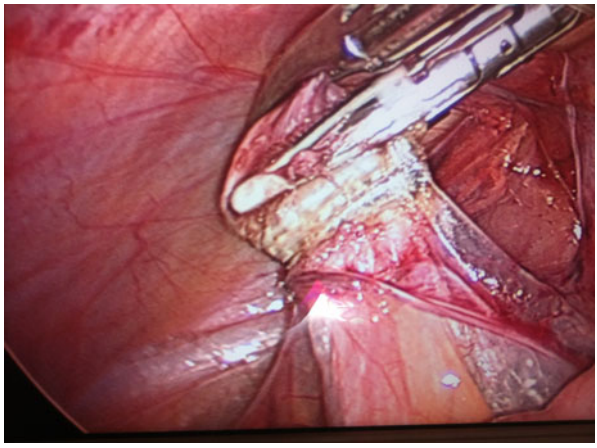

Fig. 19.7 Bipolar sealing performed 2–3 times without dividing the vascular package

prescribe narcotics postoperatively. Patients are allowed to resume full activities and bathe normally immediately. The average surgical time from skin to skin is 15–20 min.

Additional Comments

- A patent processus vaginalis might be encountered on either side during laparoscopic exploration. Repair is not indicated unless it is thought to be "clinically significant," but this is beyond the scope of this chapter.
- This technique is safe and effective in cases where there has been previous ipsilateral inguinal surgery performed [11]. More extensive dissection of the left colon made be required, as well as adhesiolysis to find a safe window for the

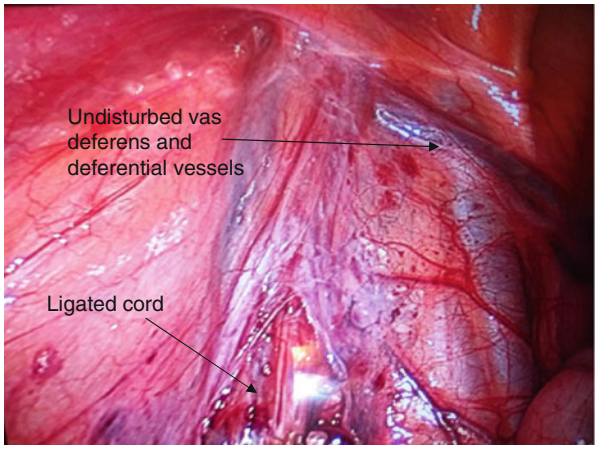

Fig. 19.8 Final inspection, ensuring no complications have occurred, and the varicocele is completely ligated

dissection. Additional ports may need to be placed in these cases to allow for exchange of instrumentation.

Outcomes and Complications

Intraoperative issues are rare, and all children are discharged the same day. In follow-up, no studies which measured testes pre- and postoperatively via orchidometer or ultrasound showed any evidence of loss of testicular size. Atassi et al. showed that the average relative left testicular volume increased by 20 % in the Palomo group, and this was not different from the group that underwent an artery-sparing procedure [12]. This is consistent with earlier work published by Kass et al. [13]. The majority of patients in the published literature demonstrated catch-up growth of the left testicle following laparoscopic varicocelectomy [14, 15]. Poon et al. compared catch-up growth between those who underwent a lymphatic sparing procedure to those who had a non-lymphatic-sparing operation and found that most demonstrated catch-up growth, regardless of the choice of procedure [16].

Laparoscopic varicocelectomy is a safe procedure, with minimal morbidity and few complications. The major complication that must be discussed preoperatively is the development of a de novo ipsilateral hydrocele. This has been reported to occur in 7–23 % of boys after left laparoscopic varicocelectomy, with 5–11 % requiring hydrocelectomy [17–22]. Patients should be followed long term following varicocelectomy to assess for hydrocele formation, as delayed presentation has been reported [18]. Varicocele recurrence rates are quite low, with reported failure rates of 0–4.7 % [14, 15, 21, 22]. Testicular loss or atrophy is a fortunately rare occurrence, despite intentional ligation of the spermatic artery.

Conclusion

Success rates following laparoscopic varicocelectomy are excellent, and serious complications are uncommon. Catch-up growth of the affected testicle is seen in the majority of patients. De novo hydrocele formation is a concern and is seen in a minority of patients but has required surgical treatment in a small subset of those following varicocelectomy. No convincing data exists to support the need for more meticulous procedures to spare the spermatic artery or lymphatics encountered during varicocele ligation. Overall, this is a safe and efficacious operation, which can be performed as an outpatient procedure with minimal morbidity and immediate return to normal activities.

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Chapter 20
Disorders of Sex Development (DSD) and Laparoscopy

Chris P. Kimber and John M. Hutson

Abstract DSD represents a spectrum of disorders. In the most common variant 46 xx DSD, laparoscopy is rarely if ever indicated. However, in other diagnoses, laparoscopy may be performed both for diagnostic and therapeutic indications. These include ovotesticular DSD, presence of a gonad with malignant potential, and the persistence of Mullerian structures, and in those with complex morphological abnormalities. Complications are those that are generally associated with any open laparoscopic procedure of the abdomen and pelvis but with the potential for damage to the gonads and internal genital tracts. Proper patient selection is important in order to minimize the risk of complication.

Keywords Intersex • Disorders of sexual development • Malignant • Gonads • Dysgenetic

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Table 20.1 Insufficient virilization

1. Genetic male 46XY with defect androgen synthesis and/or action
2. Biosynthetic defects
3. Androgen resistance (mutation in androgen receptor and/or transport)
4. Gonadal differentiation defects (i.e., streak gonads or dysplastic testes, mixed development chromosomal defects with gonadal asymmetry):
(a) Mixed chromosome DSD with mixed gonadal dysgenesis (45XY/45XO)
(b) Ovotesticular DSD 46XY, 46XX

Significant intersex anomalies occur in up to 1 in 5,000 live born infants. These anomalies are caused by the following factors [1, 2]:

1. Anomalies predictable by endocrine principles and these include defects in:
   (a) Genetic sexual determination
   (b) Gonadal differentiation
   (c) Hormonal production and action
2. Anomalies not predictable by endocrine principles:
   (a) Morphological disorders of the perineum

A child's gender is decided by its endocrine status, its morphological status including the possibility of fertility, and the prognosis for sexual function. In addition, the child's mental status and the likely gender behavior must be considered. These decisions are complex, individualized, and changing constantly with social expectations. Laparoscopy may have a role in aiding diagnosis in areas of insufficient virilization or mixed development (see Table 20.1).

Indications

Laparoscopy has a role in DSD in several areas. In the initial assessment period, it may significantly aid diagnosis by determining the internal genital structures and gonadal type. This may ultimately influence the decision of gender assignment and the prognosis given to the parents regarding fertility. Laparoscopy is also used for surgical resection of internal structures, including Mullerian remnants, utriculi, and incompletely virilized structures. It is also useful for assessment and management of the gonad, in particular the removal of streak gonads or dysgenetic intra-abdominal ovotestes [3, 4].

Many straightforward DSD do not require laparoscopy. These include complete androgen insensitivity, congenital adrenal hyperplasia, and some partial androgen insensitivities. These conditions are easily evaluated by thorough endocrine and radiological workup and rarely require surgical intervention.

The indications can be summarized as follows [5]:

1. Laparoscopy may often have a role in ovotesticular DSD, where the external genitalia are asymmetrical. Of these patients, 20 % have specific lateral disease with a testis generally present on the right-hand side and the ovary on the left. In up to 30 % of cases, the disease has bilateral ovotestes. The remaining 50 % of patients have unilateral disease with a solitary ovotestis and a normal ovary or a testis on the contralateral side. Ovotesticular DSD often requires accurate gonadal assessment and biopsy.
2. Laparoscopy also aids in removing highly potentially malignant gonads. In mixed chromosomal DSD with mixed gonadal dysgenesis, 25 % of testes with a Y cell line will have evidence of carcinoma in situ. Half of the carcinoma in situ gonads will go on to develop a complete germ cell tumor. Laparoscopy is often worthwhile in the removal of these gonads.
3. Multiple conditions can result in persistence of Mullerian duct remnants, and enlarged utriculi are often found behind the bladder associated with severe hypospadias. Small utricular remnants are often asymptomatic and do not require any surgical treatment. Some of these young males ultimately develop recurrent utriculus infections that are worse following hypospadias repair. In these patients, laparoscopic resection of the utriculus is indicated.
4. Finally, children with complex morphological development anomalies exhibit abnormal perinea, bifid or rudimentary uteri, and dysplastic gonads. Ultrasound and MRI imaging is often unreliable in this group. Evaluation of the pelvic structures is often best achieved with laparoscopy. Preoperative patient preparation with infants with DSD requires a multidisciplinary team that includes geneticists, endocrinologists, counselors, pediatric urologists, and pediatric surgeons. A baby born with an indetermined sex is best transferred urgently to a center with appropriate expertise, so that life-threatening conditions can be excluded and laparoscopy only performed if deemed appropriate.

Preoperative Investigations

Standard preoperative investigations of a child with an indeterminate DSD include a thorough clinical assessment, ultrasonography of the perineum and pelvis, and contrast study of urogenital sinuses. Karyotyping and a comprehensive endocrine evaluation are done, including adrenal sex steroid concentrations and a hormone-binding globulin test for androgen sensitivity. Molecular genetic analysis is used to look at the androgen receptor gene and the 5-alpha reductase gene. Many of these investigations can be completed in a 48-h neonatal period, and laparoscopy is rarely required. There are several infants where the diagnosis and internal assessment still remains in doubt and the picture is mixed. In this case, laparoscopic evaluation of the pelvic contents and gonadal biopsy is indicated in the neonatal period.

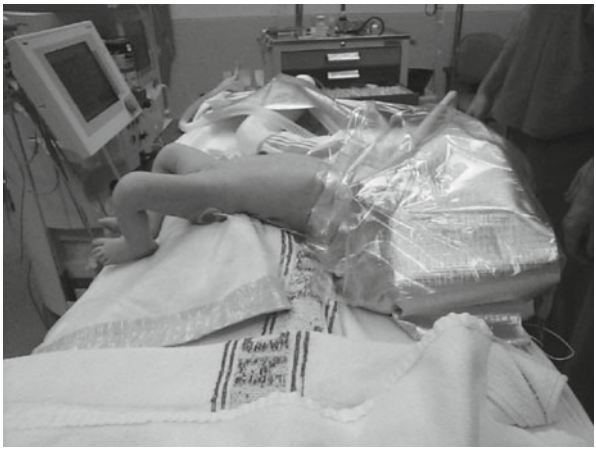

Fig. 20.1 Patient position for neonatal DSD case

Operative Technique

Procedure 1: Evaluation of Pelvic Structures for Indeterminant Gender in the Neonate

The patient is placed transversely on the operating table with the surgeons standing at the child's head and a small towel placed under the buttock to elevate the pelvis and expose the external genitalia (Figs. 20.1 and 20.2). A urethroscopy/cystoscopy/vaginoscopy is often performed prior to the laparoscopy. A 3 or 5 mm port is placed in the supra-umbilical region via an open technique. This gives an appropriate operating angle and allows adequate insufflation. The pelvis is insufflated and the intestines displaced cranially so that a clear view can be obtained. A spinal needle is introduced through the left iliac fossa under direct vision. This blunted needle is very useful for manipulation of organ structures in the neonate and allows excellent visualization. Very rarely is a second port actually required. The spinal needle is used to trace out any uterine or Mullerian structures and identify the gonads. Biopsies are rarely required at this stage but can be achieved by either directly introducing a 3 mm biopsy forceps or a Tru-Cut biopsy needle. All ligamentous and/or vasal structures are traced into the inguinal area. Any open internal inguinal ring must be explored. A gonad is often located within the inguinal canal and can be reduced into the abdomen by concomitant pressure on the groin. Each gonad in turn must be examined completely for elements of ovotestis. A full media recording should be made of the whole procedure to allow peer review and subsequent opinion over the next few days. Accurate assessment of a neonatal uterus, associated tubes, and gonads is easily undertaken by this technique.

Procedure 2: Laparoscopic Gonadal Excision

This is generally accomplished via a three-port approach with an umbilical optic port (5 mm) and two working ports (Fig. 20.3). Streak gonads are relatively easily

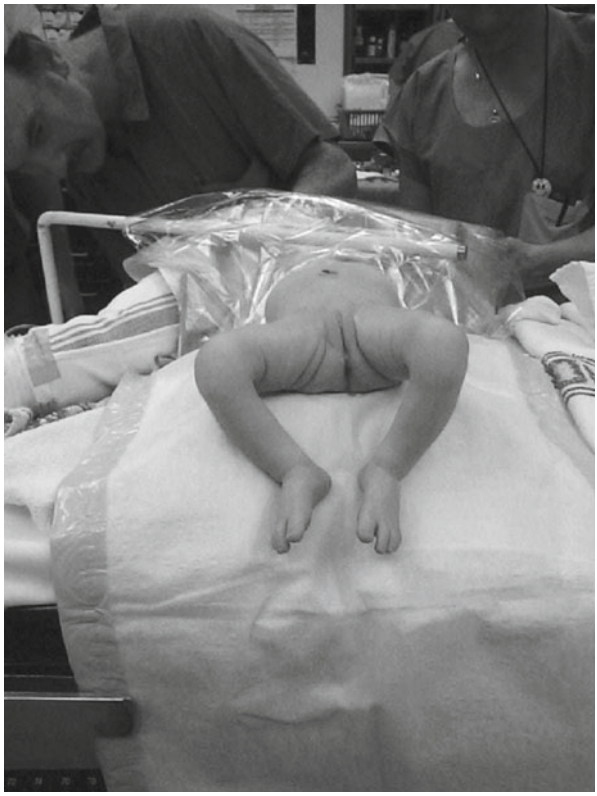

Fig. 20.2 Surgeon position for neonatal laparoscopy

identified and are best removed by preserving the fallopian tube for use in assisted reproductive techniques in the future. Simple hook diathermy or ultrasonic dissection is required to remove streak gonads. Intra-abdominal testes are easily removed in a similar fashion.

Procedure 3: Removal of Persistent Mullerian Duct Structures

An initial cystoscopy and placement of a urethral catheter with or without a ureteric catheter in the remnant is performed. A similar three-port orientation is used, but a single bladder hitch stitch is placed in the posterior bladder wall to elevate the pelvic structures. This stitch is held externally with mosquito forceps. The peritoneal reflection is opened, and midline blunt dissection occurs until a utriculus is encountered and traction on this structure allows continued dissection down into the area of the prostate.

When the utriculus enters the prostate, significant thickening of tissue occurs with some bleeding. The distal utriculus is either endolooped or suture ligated. Direct sealing with ultrasonic dissectors is not recommended. A urethral catheter is required during the procedure to avoid any inadvertent urethral tightening. Many of these procedures on children are day case procedures. I generally leave a urethral catheter in for 3–4 days, but this is not essential.

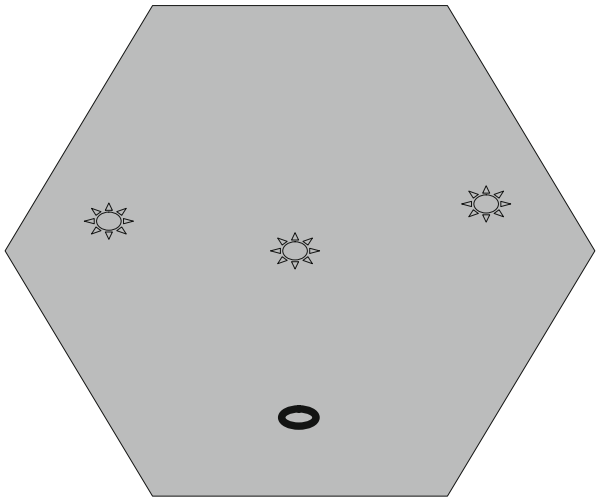

Fig. 20.3 Standard laparoscopic DSD position with three 5 mm ports and hitch stitch

Complications

Most of the techniques in laparoscopy for DSD are simple and straightforward. The major difficulties occur in the clinical decision making, particularly in mixed phenotypes such as mixed gonadal dysgenesis or ovotestis. Many errors can be made in the visual inspection of the indeterminant gonad. A thorough examination of each gonad is required. Ovarian tissue can often appear to be deperitonealized (or detunicalized) within a testes. Incomplete excision can result in inappropriate hormone production and subsequent long-term risk of malignancy.

Poor positioning of the endoloop or suture ligature on the utriculus can result in urethral stricture (too tight) or a recurrent utriculus (inadequate dissection). This can result in recurrent pelvic sepsis and subsequent frozen pelvis. Optimal care must be taken to ensure that dissection has been adequate and the clipped ligature has been placed close to the urethra without excessively tightening this structure.

Conclusion

Laparoscopy has a major role to play in many DSD. It may be useful in determining the sex of rearing and providing some prognostic indicators for fertility. The neonatal laparoscopy is reserved for accurate assessment in the rare and complex anomaly. Removal of gonadal tissue and Mullerian remnants are reasonably straightforward procedures. Careful case selection and close team coordination with the intersex team will minimize major complications and ensure appropriate case selection.

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Chapter 21
General Principles of Cystourethroscopy

Melise A. Keays and Linda A. Baker

Abstract Many children require cystourethroscopy to diagnose, characterize, or treat their genitourinary disorder. Several diseases or anomalies are best treated by cystoscopic minimally invasive means, including posterior urethral valves, ureteroceles, vesicoureteral reflux, urethral stricture/fistula/diverticulum, hematuria, urinary stones, tumors, or other rare birth defects. In this chapter, preoperative, operative, and postoperative techniques and tips of cystourethroscopy are discussed, highlighting its versatility.

Keywords Cystoscopy • Cystourethroscopy • Pediatric • Infant • Genitourinary • Anomalies

As a form of minimally invasive surgery, endoscopy of the lower genitourinary tract of the pediatric patient can achieve diagnostic and therapeutic goals for a broad range of pathological entities. Advances in instrumentation have permitted endoscopic treatment of even premature infants and in utero fetal surgery [1]. This chapter focuses on general principles of pediatric cystourethroscopy. The reader is referred to other chapters in this text for more detailed discussions of the management of other clinical entities.

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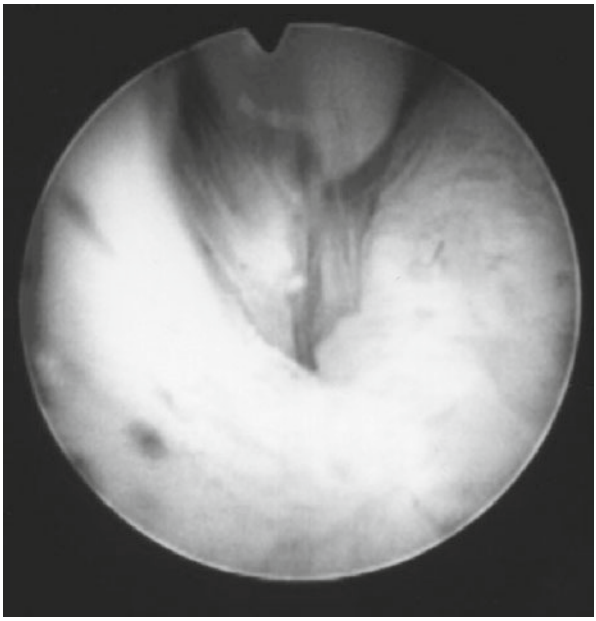

Fig. 21.1 Cold-knife incision of posterior urethral valves. The "half-moon" knife, seen in the *center* of the image, is cutting through the right valve leaflet. The verumontanum is seen in the right third of the image. The left valve leaflet is out of the image

Indications and Contraindications

Recurrent urinary tract infections (UTIs), urinary incontinence, obstructive uropathy, urosepsis, and radiological anomalies are the usual indications for lower tract endoscopy. Although many diagnoses are made before cystoscopy by using ultrasound, cystourethrography, CT scan, nuclear scan, IVP, and/or MRI, many pediatric cases require further delineation of the anatomy and physiology by endourological techniques. Cystoscopy followed by transurethral incision of posterior urethral valves for obstructive uropathy [2, 4, 5] is a common indication (Fig. 21.1). Similarly, transurethral incision of ureterocele(s) for outlet obstruction or urosepsis [3] is another clear-cut indication (Fig. 21.2), while prophylactic intervention after prenatal detection is more debated. Cystoscopically guided ureteral or bladder neck injection of bulking agents is frequently employed to treat vesicoureteral reflux (VUR) and urinary incontinence, respectively (see Chaps. 22 and 23). Some surgeons recommend routine cystoscopy before open ureteral reimplantation to assess for the configuration of a prior refluxing ureter, missed ureteral duplication (Fig. 21.3), or cystitis, which would cancel the open surgery. Male urinary incontinence should be evaluated cystoscopically after hypospadias repair or abnormal retrograde urethrogram, assessing for urethral stricture (Fig. 21.4), urethral duplication (Fig. 21.5), or urethrocutaneous fistula. In rare cases, gross hematuria in the pediatric patient may warrant study after a thorough negative medical and radiological evaluation. If clot retention occurs, clot evacuation can be achieved

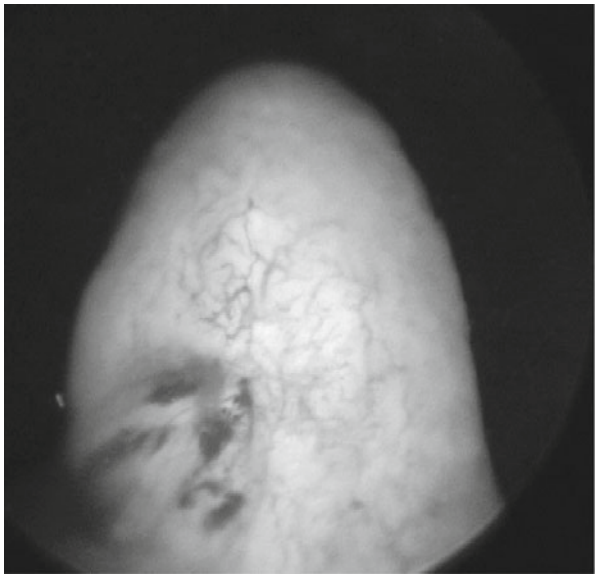

Fig. 21.2 Ureterocele. Figure shows a right moderately sized ureterocele associated with febrile UTIs, right complete ureteral duplication, and a multicystic dysplastic hydronephrotic upper pole moiety. It was transurethrally incised

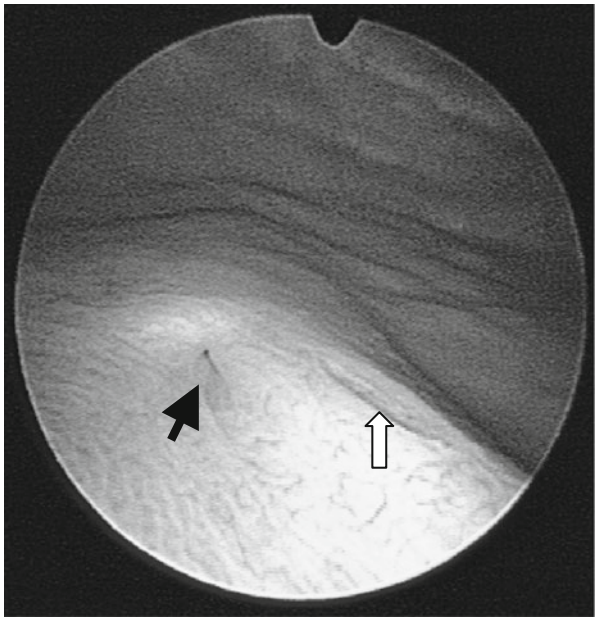

Fig. 21.3 Complete ureteral duplication. View of the right trigone reveals two ureteral orifices, the lateral, cephalad refluxing orifice (*black arrow*) serving the lower pole, and the medial, caudal orifice (*white arrow*) serving the upper pole duplex kidney

cystoscopically with the instillation of therapeutic agents if indicated. Cystourethroscopy can serve the purpose of ureteral access for retrograde or antegrade upper tract imaging and lithotripsy techniques; however, a trial of medical

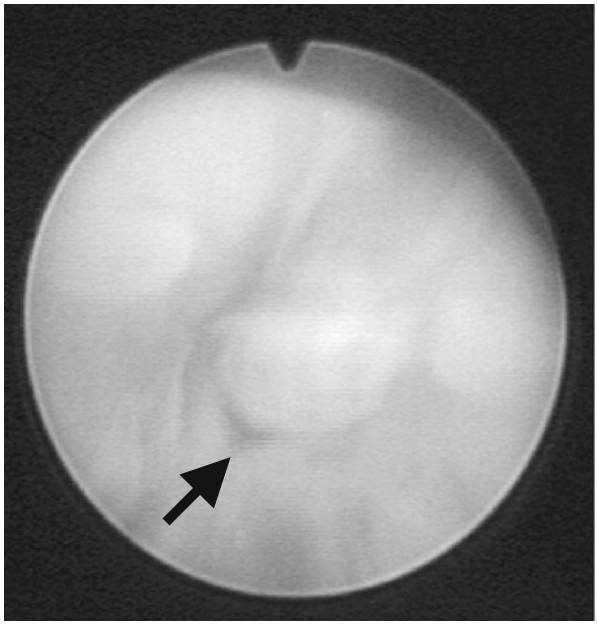

Fig. 21.4 Urethral stricture. Urethroscopy revealed a pinpoint lumen in the bulbar urethra (*arrow*) at the site of a prior visual internal urethrotomy. Open primary urethroplasty was required to correct this recurrent urethral stricture

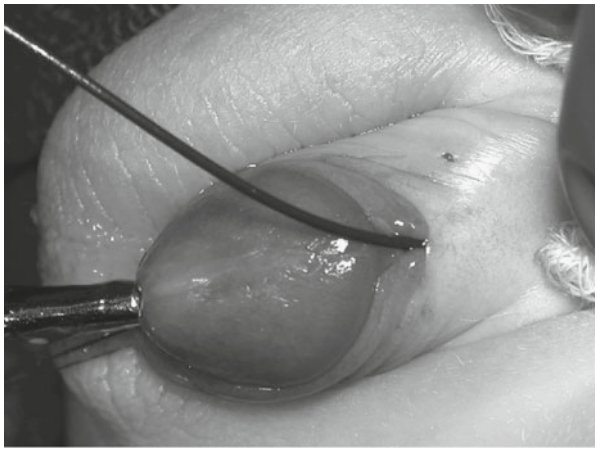

Fig. 21.5 Urethral duplication. When a dorsally foreshortened foreskin was noted, cystoscopic inspection revealed a partial urethral duplication to the symphysis. In this image, with the foreskin retracted, the *black wire* enters the dorsal nonfunctioning urethra, and the metal urethral sound enters the ventral functioning urethral meatus

therapy is warranted because many stones pass in children. Retrograde placement of an occlusion balloon at the ureteropelvic junction can prevent antegrade migration of stone fragments during percutaneous nephrolithotripsy. Retrograde ureteral stenting may be useful at the time of extensive tumor resection or at the time of laparoscopic pyeloplasty. Bladder stones can be endoscopically removed or fragmented via urethra, appendicovesicostomy, or percutaneous cystostomy approaches. At the time of cystoscopy in the child with an open bladder neck due to epispadias (Fig. 21.6) or classic bladder exstrophy, a ballooned catheter can be used for

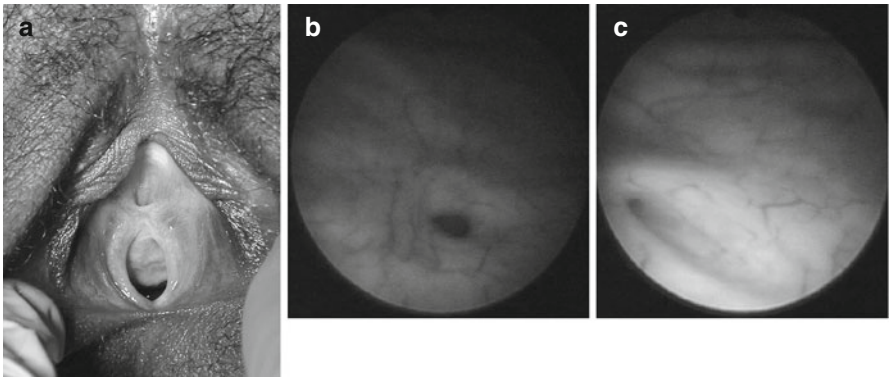

Fig. 21.6 Female epispadias with bilateral VUR. Exam under anesthesia reveasl subtle case of female epispadias associated with bilateral VUR and urinary incontinence. (**a**) External genitalia of female epispadias - note the horizontally wide urethral meatus with open urethral plate dorsally. The clitoris is bifid. The refluxing left (**b**) and right (**c**) ureteral orifices are seen

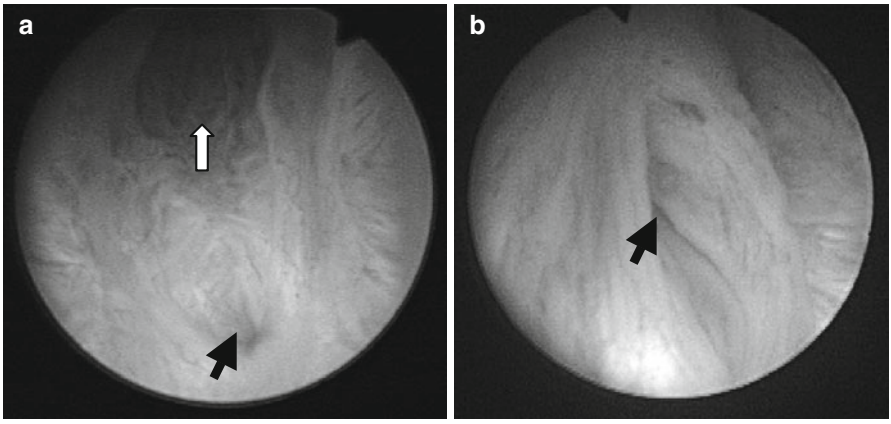

Fig. 21.7 Intersex. (**a**) Urogenital sinus of congenital adrenal hyperplasia (*CAH*). Cystourethroscopic evaluation of the urogenital sinus orifice reveals the bifurcation of the urethra (*white arrow*) and the vagina (*black arrow*). Cystourethroscopic placement of Fogarty balloons into the urethra and vagina aids the surgical reconstruction of the urogenital sinus. (**b**) Urethroscopic view of entrance into large utricle (*arrow*) on the verumontanum of an intersex patient with mixed gonadal dysgenesis

cystography to measure bladder capacity under anesthesia and assess for vesicoureteral reflux.

Cystourethroscopy with vaginoscopy is indicated in the patient with intersex (Fig. 21.7), urogenital sinus, or cloaca to delineate the surgical anatomy for repair. Tissue diagnosis of genitourinary malignancy (rhabdomyosarcoma, urothelial cancer) can be achieved by cystoscopy with tumor biopsy.

Contraindications include active bleeding disorders, hemodynamic instability, or untreated UTI/urosepsis.

Preoperative Investigation

Cystourethroscopy generally requires general anesthesia. Therefore, a standard preoperative evaluation, considering cardiopulmonary, endocrinological, and hematologic disorders that increase anesthetic risks, is necessary. Children with identified disorders may require preoperative blood chemistries, and children with congenital adrenal hyperplasia require stress steroid dosing. Preoperative radiological investigations often include ultrasound, cystourethrography, CT scan, nuclear scan, IVP, and/or MRI. Sterile urine is required to reduce risk of upper tract UTI prior to invasive instrumentation.

Preoperative Patient Preparation

Once cleared for surgery and meeting NPO restrictions, an oral sedative is given to prevent separation anxiety. At this time, IV antibiotics may be administered in the child with recurrent UTIs, depending on physician preference.

Specific Instrumentation

Most cystoscopic suites are equipped with monitors for fluoroscopic and video camera imaging, which allow multiple viewers, teaching, optical magnification, and video recording. A fiberoptic xenon light source and electrocautery are also required. Cystoscopic irrigant (sterile normal saline or sterile water) should be warmed to body temperature to diminish hypothermia. Several companies manufacture pediatric endoscopic equipment, including Wolf, Storz/Olympus, and ACMI. Given the delicate nature of this equipment, it is crucial to have several scopes available in case of equipment malfunction or unanticipated needs. Rigid pediatric cystoscopes range from 5 Fr to adult sizes, and the pubertal status of males should be noted to help judge the equipment needed. The 5 Fr "all-in-one" cystoscope is a one-piece instrument with united telescope and sheath; the 2.5 Fr to 3 Fr working channel is rather limiting. However the working channel increases in the larger scopes, with greatest caliber in the "all-in-one" cystoscopes. Other scopes consist of two pieces: the interchangeable telescope (0°, 30°, and 70°) and the sheath. A range of reusable and disposable equipment (graspers, biopsy forceps, bugbee electrode, wires, catheters, stents, balloons, baskets, laser fibers, and STING needles, to name a few) exist to achieve the indicated therapy but may be impossible if the working channel caliber is <5 Fr. Pediatric cystoscopes with an offset lens allow straight entry into the working channel. 7.5 Fr flexible or semirigid ureteroscopes should be on hand if ureteral access is necessary. Pediatric resectoscopes, ranging from 7.5 FR to adult sizes, require loops, balls, blades, or hooks unique to the FR size of the

resectoscope. Resectoscopes can be used cold or hot (with electrocautery); however, most recommend sparing use of electrocautery to minimize thermal damage and stricturing with the highest stricture rates reported with loop resection [4]. Some have used holmium or Nd:YAG laser to cut valves or strictured tissue [4, 5]. It is convenient to have urethral sounds and/or bougies available for urethral dilation if needed.

Endoscopic bladder stone management requires the use of rigid and flexible cystoscopes. If percutaneous access to the bladder is needed, cystoscopically guided suprapubic access sheaths can be quite useful and come in an assortment of sizes, with 13 Fr to 18 Fr the most useful. To achieve stone fragmentation, electrohydraulic, ultrasonic, combined ultrasonic and pneumatic (Swiss lithoclast), or holmium laser lithotripsy can be used. Rigid probes include the electrohydraulic probes (3 Fr or 5 Fr), ultrasonic probes (as small as 5 Fr), and the Swiss lithoclast (3.3 and 3.8 mm). Of the flexible probes, holmium laser fibers are 200, 400, 600, or 1,000 μm, and Swiss lithoclast has a 0.9 mm flexible pneumatic probe.

Operative Technique

After the induction of anesthesia, the patient is properly padded, positioned, and grounded for electrocautery. In the infant, the supine frog leg position may be adequate; however, an alternative is dorsal lithotomy position with leg suspension via towel rolls and tape at the padded knees. If fluoroscopy is not necessary, position the infant close to the anesthesiologist perpendicular on the bed to increase anesthetic safety (Fig. 21.8). Otherwise, the child will need to be moved down on the foot of the bed so the fluoroscopy arm can pass beneath (Fig. 21.9). The older child should be placed in dorsal lithotomy position with the legs in properly fitted stirrups.

Prior to the surgical preparation, a thorough examination under anesthesia is performed. The external genitalia are closely inspected for anomalies (genital configuration (Fig. 21.10), masses (Fig. 21.11), or ectopic orifices (Fig. 21.12)). After securing properly functioning instrumentation, a lubricated cystoscope is chosen of appropriate size for the child.

Cystourethroscopy of a female is straightforward, and often the greatest challenge is entering the urethral meatus. To minimize bacterial contamination, every effort should focus on endoscopy of the urethra and bladder prior to vaginoscopy. In some challenging cases, the urethral meatus can be identified by gentle outward (not lateral or downward) pull on the labia majora and can be found in a hypospadic position in some. The female urethral meatus should accept a 7.5 Fr to 8 Fr cystoscope in the term infant. Although the female urethra is significantly shorter than the male urethra, it shares the same mucosal vascular striations of the posterior urethra of the male, which should run parallel to the cystoscope. The female urethra is coapted to the bladder neck. On bladder entry, the yellow urine should be evacuated to aid visualization. Once distended with irrigant, the bladder should appear spherical with smooth walls and homogenous epithelium. One slit-like ureteral orifice is

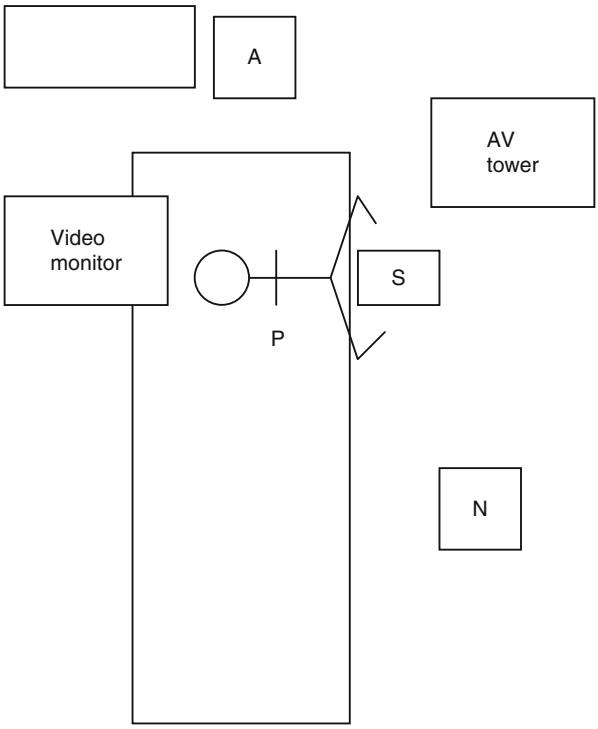

Fig. 21.8 If fluoroscopy is not necessary, position the infant close to the anesthesiologist perpendicular on the bed to increase anesthetic safety

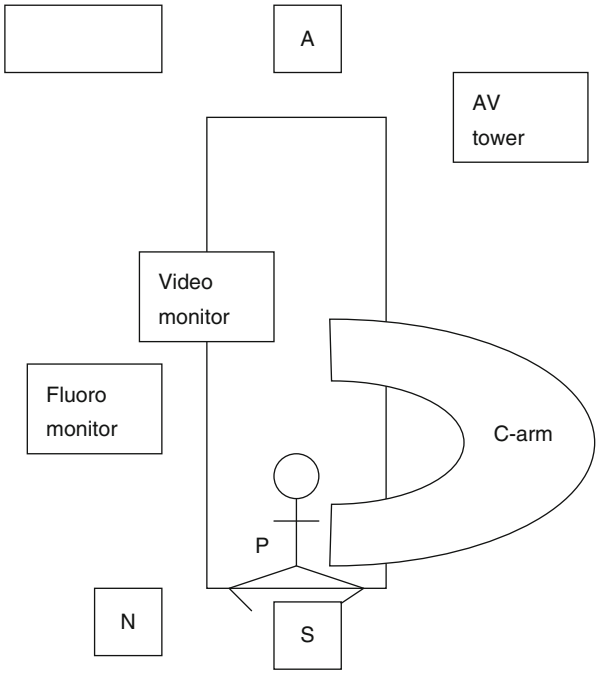

Fig. 21.9 If fluoroscopy is necessary, the child will need to be moved down on the foot of the bed so the fluoroscopy arm can pass beneath

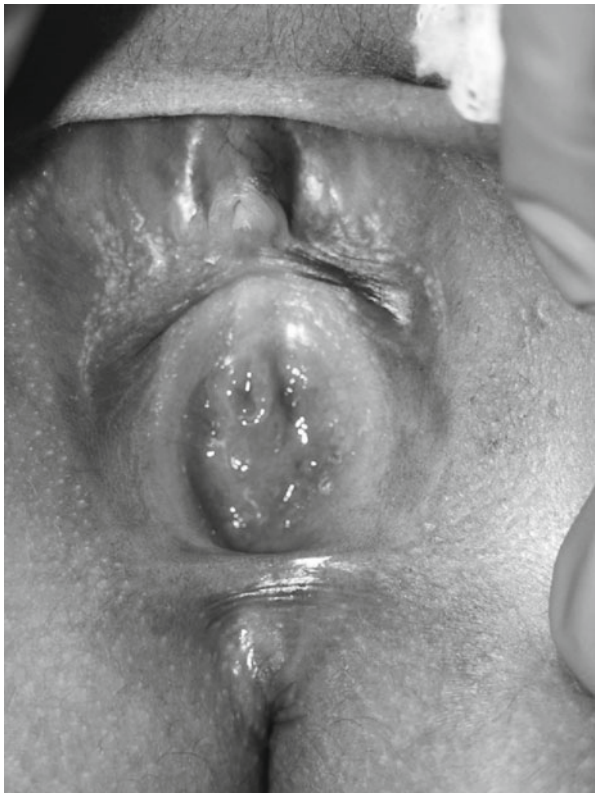

Fig. 21.10 Vaginal agenesis. A thorough examination under anesthesia reveals complete vaginal agenesis in a prepubertal child with solitary kidney

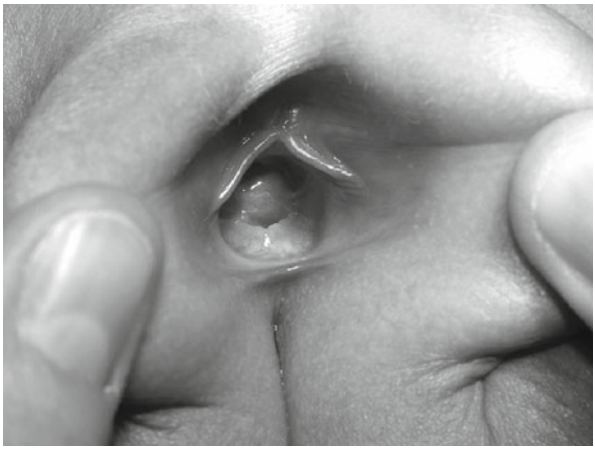

Fig. 21.11 Perineal mass. A thorough examination under anesthesia reveals perineal mass which bulges with valsalva. The mass was a right upper pole large ectopic ureterocele. Radiographic contrast was needle injected into the mass, retrograde filling the massively dilated upper pole ureter. Cystoscopic retrograde right lower pole ureterogram revealed an equally massive lower pole grade 5 refluxing ureter. The entire right kidney was nonfunctional and removed laparoscopically

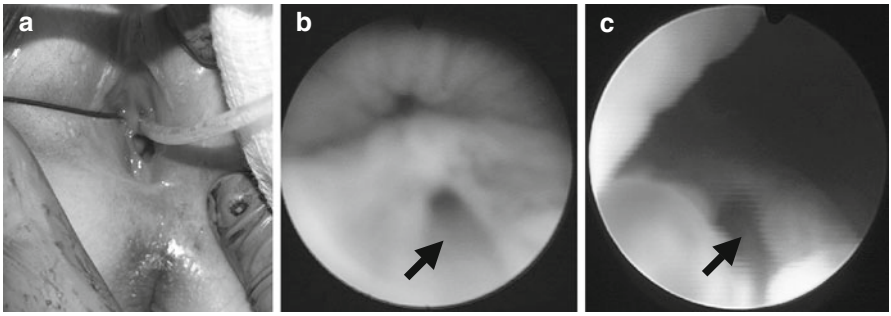

Fig. 21.12 Ectopic ureters. (**a**) A thorough exam of an incontinent female under anesthesia detected a right ureter exiting on the perineum. The opaque catheter is in the urethra, and the black wire enters the ectopic ureteral orifice. One left and one right orthotopic ureteral orifices were seen within the bladder cystoscopically. Vaginoscopy revealed an ectopic left upper pole ureteral orifice just within the hymenal ring. This child had bilateral complete duplication with bilateral upper pole ureteral ectopia. (**b**) In a different patient, cystourethroscopic view of an ectopic left upper pole ureter (*arrow*) entering the female urethra. (**c**) An ectopic right ureter entering the top of the verumontanum serves this solitary functioning kidney in a male patient with recurrent febrile UTIs, Grade 5 left VUR, right trigonal diverticulum, and incompetent bladder neck. Intravenous administration of indigo carmine proved useful in locating the single system orifice (*arrow*), as blue dye consistently swirled from behind the tip of the cystoscope positioned cephalic to the bladder neck

usually seen on each lateral edge of the trigone, a triangular zone on the floor of the bladder. Pubertal estrogens will stimulate normal squamous metaplasia changes on the trigone. The location, number, and configuration of the ureteral orifices are noted, as abnormal orifices may reflux. The experienced cystoscopist will monitor the quantity of irrigant within the bladder, preventing overdistension and mucosal hemorrhage. If indicated, the same scope can be atraumatically passed thru the hymen into the vagina. To achieve complete visualization, the vaginal introitus must be compressed with gauze sponge to gain distension with irrigant. One midline cervix with os is typically seen with no vaginal mucosal or muscular wall lesions (Fig. 21.13). In general, the female urethra, bladder, and vagina are thoroughly inspected for possible anomalies, which are listed in Table 21.1.

Cystourethroscopy of a male varies from the female procedure mainly by techniques to negotiate the male urethra. In the term, male pediatric patient, the urethra typically can accept a 7.5 Fr or 8 Fr caliber cystourethroscope. Occasionally, the foreskin and the urethral meatus will require dilation in order to admit this. The cystoscope tip is inserted with lubricant. With flow on, the scope is negotiated thru the uniform tubular anterior urethra. At all times, the lumen should be visualized ahead or the scope should be backed until lumen is seen. At the external urethral sphincter, the urethra becomes tighter even with irrigant flow. The mucosal vascular striations begin in this zone, indicating entry into the posterior urethra. At this point, the urethra turns sharply upward. To negotiate this turn, the cystoscopist must lower the penis, so the camera and eyepiece of the scope are below the level of the buttocks. As the scope is advanced, the round raised pink verumontanum is seen on the

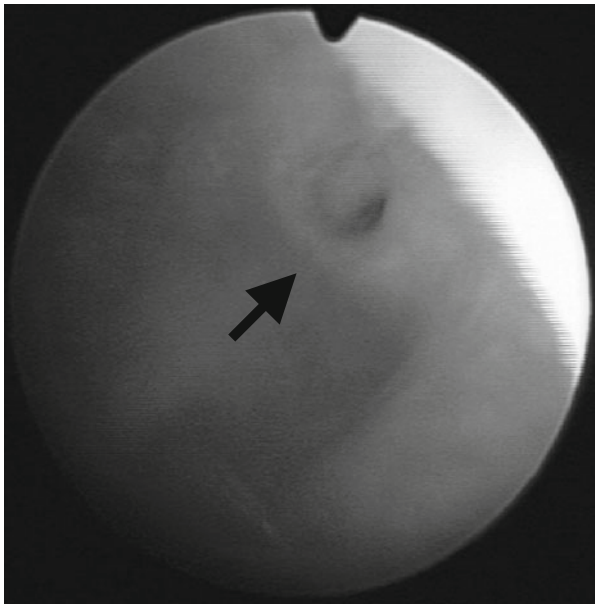

Fig. 21.13 Vaginoscopy. With irrigant filling the vagina, the vaginoscopic appearance of a prepubertal cervix and its os is seen (*arrow*)

dorsal midline of the urethral wall. The bladder neck follows the verumontanum and then the bladder is entered. It is cystoscopically identical to the female bladder. The male urethra and bladder are thoroughly inspected for possible anomalies, which are also listed in Table 21.1.

Several other general cystoscopic tips are discussed below:

1. Posterior urethral valves are an obliquely oriented membrane extending from the distal verumontanum and attaching anteriorly to the urethral wall, with a small eccentric aperture. Prior urethral catheterization often alters the form of the valves. In the older child, minivalves can be missed. To improve detection, the bladder should be filled retrograde via the cystoscope. With the irrigant flow shut off, the cystoscope is placed just distal to the external sphincter, and the Credé maneuver is performed. Antegrade flow will further open the valve leaflets. An alternative method is to guide a resectoscope hook blade in the troughs lateral to the verumontanum. Membranous valve leaflets can be identified and cut at 5 o'clock and 7 o'clock with this technique. Several techniques, such as electrocautery, Fogarty balloon, or laser, have been used to ablate/fragment PUV [2, 4, 5], urethral polyps, or urethral strictures. The author's preference is cold-knife incision, followed by temporary catheterization; this technique may result in less tissue damage. In the preterm male infant with obstructive uropathy, cystourethroscopy may be impossible if the urethra is small. To circumvent this problem, some have performed antegrade posterior urethral valve ablation via percutaneous cystotomy access effectively [7]. If this is also ineffective, a Foley catheter, suprapubic catheter, or vesicostomy may be necessary to temporarily divert the obstructed system.

Table 21.1 Genitourinary anomalies identified by cystourethroscopy

Sex of child	Location of pathology	Pathology	Cystoscopic findings	Therapy options
Male or female	Anterior urethra	Urethral diverticulum	Dilated cavernous segment of urethra. In males, may have a wide mouth in the penoscrotal region +/– purulent debris or hair. In females, small mouthed with mass effect	Open urethroplasty
Male		Urethral stricture	Mild narrowing to pinpoint narrowing of urethral lumen, short membrane, or long narrowed segment with whitish scarred epithelium	Endoscopic (VIU) via resectoscope or open urethroplasty
Male		Anterior urethral valves	Fenestrated diaphragmatic membrane or mucosal cusp arising from the ventral wall of the bulbar, penoscrotal, or penile urethra	Endoscopic incision or open urethroplasty
Male or female		Urethral duplication	Additional channel with or without communication to the ventral urethra or bladder	Test for communication via contrast or indigo carmine injection
Male		Megalourethra	Marked penile urethral dilation	Open urethroplasty
Male	Posterior urethra	Posterior urethral valves	Valve leaflets at the verumontanum. Bladder neck hypertrophy. Posterior urethral dilation. Bladder trabeculation	Endoscopic transurethral resection of posterior urethral valves (TUR valves) or urinary diversions
Male or female		Ectopic ureteral orifice	Male orifice proximal to the external sphincter on veru or posterior urethra. Female orifice in the bladder neck, urethra, perineum, vagina, or cervix. If functional, can be identified by indigo carmine excretion	If symptomatic, open surgery (ureteral reimplantation, ureteroureterostomy, heminephroureterectomy)
Male		Prostatic utricle/vaginal remnant	Frondlike mucosal projections surrounding orifice to utricle/vaginal remnant on the center of the verumontanum	If symptomatic, endoscopic fulguration of orifice or laparoscopic/open resection of utricle
Male or female	Bladder neck	Ectopic ureteral orifice	Stenotic or gaping orifice at the bladder neck. If functional, can be identified by indigo carmine excretion	If symptomatic, open surgery (ureteral reimplantation, ureteroureterostomy, heminephroureterectomy).

Male or female	Trigone/ureteral orifices	Ureterocele	Deformed trigone with ballooning bladder mucosa. May extend into bladder neck, urethra, and perineum	Anatomy can be defined by needle retrograde ureteropyelogram. If indicated, transurethral incision of ureterocele for decompression
Male or female		Deformation of the floor	May be feces, megaureter, or ureterocele	Consider fecal disimpaction, retrograde ureterogram, or ureterocele incision
Male or female		Tumors	Papillary or sessile. Often bleeding. Screen in an augmented bladder with gross hematuria, new pain, new incontinence or >4 symptomatic infections/year, abnormal US, or >50 RBC/HPF [6]	Cold cup biopsy for diagnosis. Consider endoscopic resection
Male or female		Ureteral duplication	Distal, medial orifice serves the upper pole moiety. Proximal, lateral orifice serves the lower pole moiety	May require no intervention. Retrograde ureterography may confirm occult or partial duplication. Consider STING for VUR if indicated
Male or female		Diverticula	Hutch diverticula are adjacent to the ureteral orifice (paraureteral). Periureteral diverticula may have the ureteral orifice within the diverticulum	Typically no intervention. May be resected at ureteral reimplantation
Male or female		Patulous ureteral orifice	Ureteral orifice configurations are not predictive of vesicoureteral reflux	If indicated, STING of refluxing ureter

continued

Table 21.1 (continued)

Sex of child	Location of pathology	Pathology	Cystoscopic findings	Therapy options
Male or female	Bladder	Trabeculation	Irregular small bands of hypertrophied detrusor muscle beneath the bladder mucosa	Evaluate etiology (obstruction, neurogenic cause, functional elimination disorder) and treat
Male or female		Diverticula	May have a small or large mouth to the small or large sac	May require resection if recurrent UTIs unresponsive to medical therapy
Male or female		Calculi	Free-floating stone in the bladder or diverticulum	Open or endoscopic stone ablation techniques
Male or female		Urachal anomalies	Urachal diverticulum may be seen in prune belly syndrome. Urachal sinus may appear infected at the dome	Resect open or laparoscopically
Female	Urogenital sinus		The orifice beneath the clitoris is the urogenital sinus. It biforates at a variable distance into the urethra and vagina	Total urogenital sinus mobilization
Female	Vagina	Duplication/septation	Hematometrocolpos may cause mass. Septum can be horizontal or vertical and partial or complete. May see two cervices	Perforate obstructing membranes. Resect septum. May require formal vaginoplasty
		Imperforate hymen	Bulging perineal mass	Incision of hymen. Assess for urinary obstruction
Female		Foreign object	Persistent vaginal discharge prompts vaginoscopy, identifying the object	Removal of foreign object
Female		Cloaca	Single perineal opening with variable configurations leads to the urethra, vagina, and anorectum	Diverting colostomy and possible urinary diversion. Total mobilization of the cloaca

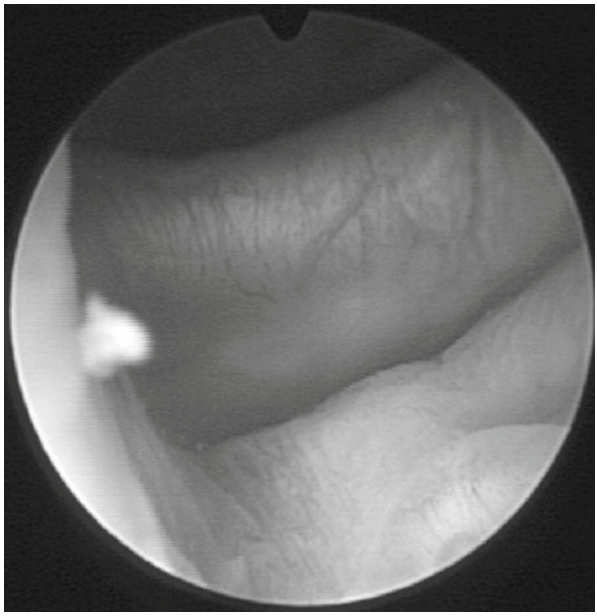

Fig. 21.14 Bladder diverticulum. Large wide-mouthed trigonal diverticulum viewed from the incompetent deformed bladder neck (Same patient as Fig. 21.12c)

2. Bulging masses on the trigone may be the result of a significant fecal impaction elevating the floor of the bladder or, alternatively, a megaureter or large ureterocele. Needle retrograde injection of contrast can delineate ureterocele versus megaureter and can define their extent toward the perineum.
3. On the trigone, inspection of the ureteral orifices may reveal a hutch diverticulum. All trigonal diverticula (Fig. 21.14) should be inspected with low volumes of intravesical irrigant to rule out an effacing ureterocele.
4. The configuration of the ureteral orifice can be variable even within normal patients but oftentimes takes on a golf-hole configuration when vesicoureteral reflux is present.
5. If double J ureteral stenting is planned in the male child, a two-piece scope is crucial. In this case, once wire access is achieved within the ureter, the scope is withdrawn, and the sheath only is back loaded on the wire. Under fluoroscopic guidance, the stent can then be passed over the wire through the cystoscope sheath positioned over the ureteral orifice, preventing wire coiling within the bladder.
6. In the intersex patient, close inspection of the verumontanum may show frondular projections around a central orifice, a hallmark sign indicating a prostatic utricle/vaginal remnant (Fig. 21.7). The lengths of the urogenital sinus, vagina, and urethra aid surgical planning. Cystoscopically guided placement of Fogarty balloons into the urethra and vagina of a urogenital sinus can guide surgical repair.

Postoperative Management

Routine postoperative care is indicated, and most cases are performed on an outpatient basis. If purulence was detected, then antibiotics should be administered.

Complications

Possible complications can include bladder or urethral perforation, hemorrhage, pain, urinary retention, ureteral obstruction, infection, and urethral or ureteral trauma with stricture formation or irritative voiding symptoms. Fortunately, these are rare.

Author's Remarks

Cystourethroscopy is an extremely versatile tool for the urologist. It is used to confirm clinical suspicion of disease or to delineate the unusual case. As the technology has advanced, endoscopic tools have permitted minimally invasive therapeutic interventions. In many cases, these procedures negate the need for open reconstructive surgery and have revolutionized the management of these disorders.

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Chapter 22
Endoscopic Injection Techniques for Vesicoureteral Reflux

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Abstract Vesicoureteral reflux (VUR) is the retrograde flow of urine from the bladder to the upper urinary tract and is one of the most prevalent urologic diagnoses in children. Management options include observation with or without continuous antibiotic prophylaxis and surgical correction via endoscopic, open, or laparoscopic/robotic approaches. Surgical intervention may be necessary in children with persistent reflux, renal scarring, and recurrent febrile urinary tract infections or in cases of parental choice. Endoscopic treatment of VUR is an outpatient procedure and is associated with decreased morbidity compared to ureteral reimplantation. The classic subureteral Teflon injection (STING) technique is the most commonly described method and is now frequently referred to as subureteral transurethral injection. It involves injecting a bulking material below the ureteral orifice, providing tissue

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augmentation under the refluxing orifice thereby increasing the submucosal length of the ureter and creating a fixation point to enhance the valve mechanism. The concept of ureteral hydrodistention and intraluminal submucosal injection (hydrodistention implantation technique or HIT) has led to improved success rates in eliminating reflux. Modifications of the double HIT technique now include proximal and distal intraluminal injections that result in coaptation of both the ureteral tunnel and orifice.

Keywords Vesicoureteral reflux (VUR) • Endoscopic injection • Subureteral transurethral injection (STING) • Hydrodistention implantation technique (HIT)

Introduction

Vesicoureteral reflux (VUR) is one of the most common urologic diagnoses affecting children, with an estimated prevalence of 0.4–1.8 % in the general pediatric population and 30 % in those with a history of febrile urinary tract infection (UTI) [1, 2]. Optimal management remains controversial, and options include observation with or without continuous antibiotic prophylaxis and surgical repair. An individualized risk-based approach that takes into consideration a multitude of demographic, radiographic, and clinical factors should guide management [3]. Endoscopic repairs correct VUR by injection of a bulking substance that allows elevation and coaptation of the ureteral orifice and detrusor tunnel [4]. This chapter will focus on the endoscopic correction of VUR, as well as patient selection and potential complications.

Endoscopic Techniques

Matouschek first described endoscopic correction of VUR using a bulking agent in 1981 as an alternative to continuous antibiotic prophylaxis or ureteral reimplantation [5]. In 1984, O'Donnell and Puri further advanced this concept by performing subureteric injections using Teflon paste═coining the term "STING" (subureteric Teflon injection)[6]. In 2004, Kirsch and co-workers further modified the injection procedure by injecting *within* the intraluminal ureteral mucosa to achieve total ureteral tunnel coaptation using the hydrodistention implantation technique (HIT) followed by the double HIT, which involves proximal tunnel and distal orifice intramural injections [7, 8]. The ideal injectable material should be durable, effective, safe, and should not extrude or migrate. Currently, the only FDA-approved bulking agent is dextranomer hyaluronic acid copolymer [Deflux®]. Endoscopic injection has become the most common worldwide means of correcting VUR because of its minimal invasiveness and high success rates (Video 22.1).

Patient Selection

Spontaneous resolution of primary reflux is common secondary to remodeling of the ureterovesical junction (UVJ), elongation of the intravesical ureter, and stabilization of bladder dynamics. Resolution depends on initial grade of reflux, gender, age, voiding dysfunction, presence of renal scarring, and timing of VUR on a voiding cystourethrogram [3, 9]. Management is therefore individualized and based on patient age, health, VUR grade, clinical course, renal scarring, and parental preference. Indications for correction of VUR include moderate-to-high-grade reflux (grades III–V), low probability of spontaneous resolution, renal scarring, recurrent pyelonephritis, breakthrough febrile UTI while on continuous antibiotic prophylaxis, and parental preference [10, 11].

Endoscopic Injection Techniques

Patient Positioning and Equipment

The child is placed in the dorsal lithotomy position after induction of general anesthesia. The ability to rotate the cystoscope over the child's thighs is important, in order to adequately visualize and inject laterally displaced orifices. An offset lens should be utilized to permit direct passage of the needle in line with ureter without damaging the needle. Several needles are available for injection, including a straight metal needle as well as a filiform needle guide (Injekt® needle). The bladder should be filled to less than half its capacity during injection in order to prevent high tension within the detrusor muscle.

STING Technique

In the traditional STING procedure, the needle is introduced *under* the bladder mucosa 2–3 mm below the refluxing orifice at the 6 o'clock position, and the injection is continued until there is a prominent bulge within the orifice assuming a crescent-like shape [4, 6]. The injected material augments the tissue below the ureteral orifice, providing a solid support under the refluxing ureteral orifice. This is thought to increase the submucosal ureteral length and create a fixation point whereby the valve mechanism may be enhanced preventing retrograde reflux of urine. One concern regarding the STING method is potential caudal migration of material, particularly of low injected volume, which may result in longer-term failure despite initial coaptation. The relatively low success of the STING method compared to open ureteral reimplantation has led our group to develop the HIT and double HIT methods described below.

Table 22.1 Classification of the ureteral orifice using hydrodistention (HD) grade

Ureteral HD grade	Endoscopic findings
H0	No orifice distension evident
H1	Orifice opens, intramural tunnel not evident
H2	Intramural tunnel evident, extramural tunnel not evident
H3	Extramural tunnel evident or ureter can accept the cystoscope

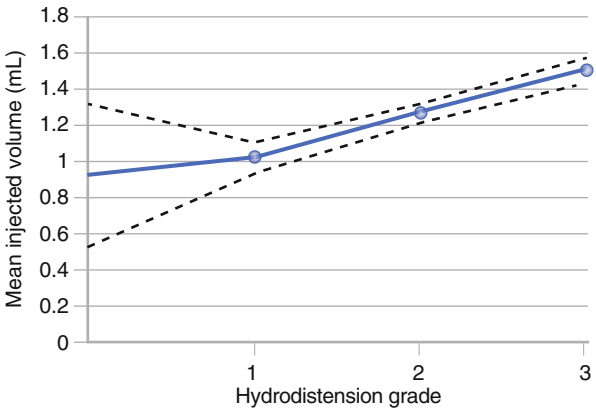

Fig. 22.1 Injection volume based on HD grade. The injected volume increases significantly with each increase in HD grade from H1 to H3. The bold line represents the average injected volume. *Dashed lines* represent the 95 % confidence intervals for the mean

HIT and Double HIT Methods

Endoscopic injection techniques have evolved from subureteric injections (STING) described above to intraluminal injections (HIT and Double HIT) [8]. Hydrodistention is performed with the tip of the cystoscope placed at the ureteral orifice; a pressure stream is achieved by placing the irrigation bag approximately 1 m above the pubic symphysis on full flow. Hydrodistention is graded according to the distensibility of the orifice (Table 22.1) and allows visualization of the intraluminal injection site as well as assessment of injection progress. Ureteral hydrodistention (HD) causes the orifice to open before treatment. Following proper implantation, the ureter should remain closed with an H0 grade. Hydrodistention grading correlates with VUR grade, with higher HD grades requiring more injected volume [8, 12]. By virtue of the technique, larger volumes are used when applying the double HIT method. In a series of 516 treated ureters from our institution, volume of injection was similar for VUR grades I–III, while a significantly higher volume was needed for VUR grades IV–V [4]. However, a progressively higher volume of injection was required as the HD grade increased from H0 to H3, as shown in Fig. 22.1. Although HD grade clearly plays a significant role determining injection volume, surgeon experience, tissue plains, and redo operations also contribute to the volume necessary to achieve an H0 ureter.

When employing the double HIT methodology, the needle is placed into the ureteral orifice and inserted in the mid-ureteral tunnel at the 6 o'clock position after performing ureteral hydrodistention. This differs from the STING technique, where the needle is inserted 2–3 mm *below* the refluxing orifice. Bulking agent is injected until a sufficient bulge is produced, which coapts the detrusor tunnel. A second injection at the distal most aspect of the intraureteral tunnel results in coaptation of the orifice (Fig. 22.2). Hydrodistention with the bladder nearly empty is performed following each injection to monitor progress. Additional injection(s) may be needed to achieve an H0 ureter during hydrodistention.

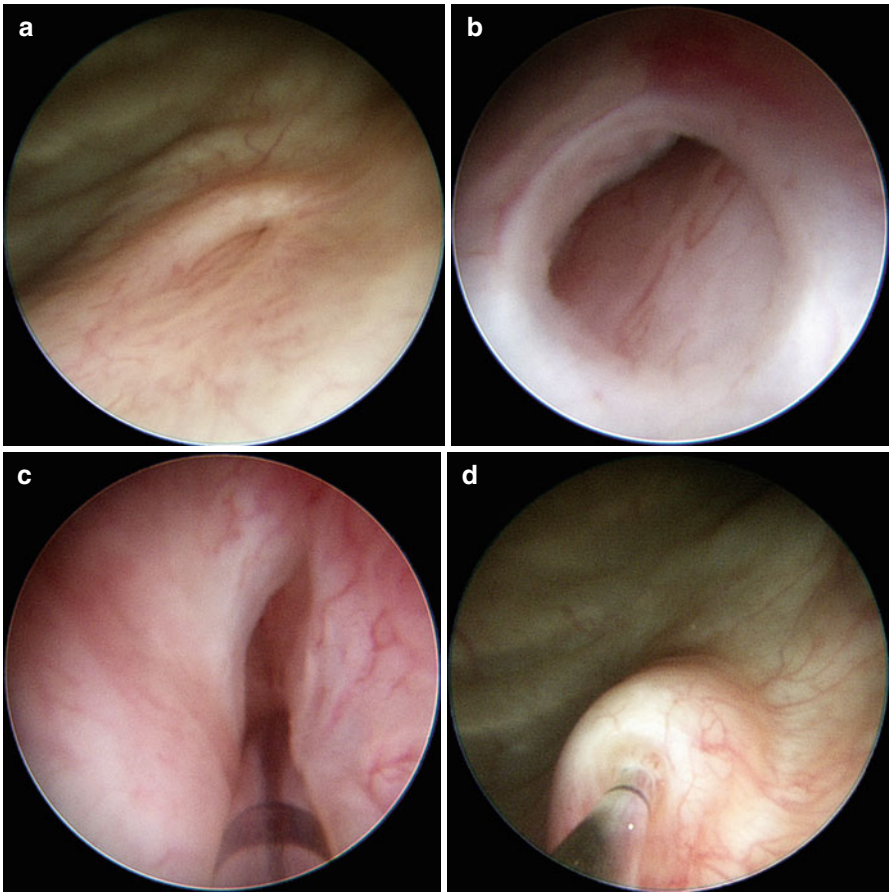

Fig. 22.2 Double HIT method. The bladder is emptied and the ureteral orifice visualized (**a**), followed by hydrodistention (**b**). The proximal HIT is performed with the needle inserted into the mid-ureteral tunnel at the 6 o'clock position (**c**), and sufficient bulking agent is injected to produce a bulge which coapts the detrusor tunnel (**d**). The distal HIT (**e**) leads to coaptation of the ureteral orifice (**f**). The double HIT coapts both the detrusor tunnel and the ureteral orifice and results in non-distensibility of the ureteral orifice (H0)

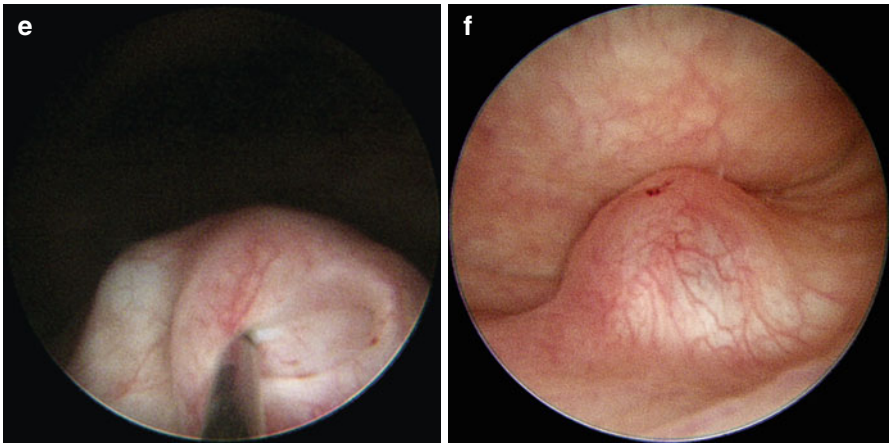

Fig. 22.2 (continued)

Clinical and Radiographic Outcomes Following Endoscopic Injection

The clinical success of any type of anti-reflux surgery can be measured radiographically (absence or downgrading of VUR) and clinically (absence or decrease in frequency of febrile urinary tract infections). In the medical literature, there is considerable variability as to how success is measured; therefore, true surgical outcomes are difficult to ascertain [13]. The average resolution of VUR following a single endoscopic injection is 83 % based on aggregate data, though success rates have ranged from 70 to 95 % [11]. In our long-term experience with the double HIT method, both radiographic and clinical successes at 1-year follow-up were 93 % [14]. Importantly, 95 % of patients avoided open surgery during a 4-year follow-up [13].

Preventative Measures to Avoid Complications

Families should be thoroughly counseled regarding the various VUR management options, and all children should undergo screening for and treatment of bowel/bladder dysfunction. In addition to proper patient selection, there are a number of technical principles that can help to ensure a successful outcome. Proper injection technique, selection of correct injection site(s), adequate injected volume, and recognizing the endpoints of the injection are all important components of the injection procedure necessary to follow in order to avert failure. Volume of injection varies depending on the injection method(s). As stated above, the HD grade of the ureter should directly correlate with the volume used when the double HIT method is employed. It is important to note that although higher grades of VUR are associated with higher HD grades, even lower grades of VUR may have high HD grades and require increased

volumes of injection [12]. After injection, the bladder should be emptied and hydrodistention repeated to confirm the absence of ureteral distensibility (i.e., H0 ureter).

Complications

Complications can be categorized into those that occur in the immediate postoperative period and those that manifest as long as several years from the time of surgical intervention. Early complications typically occur within the first 48 h following injection and are often transient. Less than 4 % of children undergoing endoscopic VUR therapy complain of flank pain or nausea postoperatively and nearly all resolve with analgesics. Ureteral obstruction following endoscopic injection occurs in approximately 0.6 % of patients and is frequently associated with voiding dysfunction, secondary VUR, or with larger ureters when a large volume of bulking agent is injected [4, 11]. If anuria or oliguria persists beyond 24 h, a renal bladder ultrasound and serum creatinine level should be obtained to exclude obstruction. Complete obstruction requires placement of either ureteral stents or nephrostomy tubes to allow upper tract drainage. The latter might be preferable because the obstruction may be transient, and resolution can be anticipated when the hyaluronic acid component dissipates within 2 weeks of the injection. Hematuria and bladder spasms are frequent complications of ureteral reimplantation, but these complications are rare following endoscopic treatment.

It is not uncommon for patients to develop a febrile urinary tract infection after endoscopic injection. Checking the urine preoperatively and beginning appropriate antibiotics if indicated can usually avoid this. In patients with a symptomatic UTI, surgery should be postponed.

Postoperative reflux may be the result of uncorrected, ipsilateral, or new onset contralateral reflux. Although persistent reflux may be the result of the aforementioned reasons for failure of the procedure, it often is the result of overt bladder pathology (neurogenic bladder or anatomical anomalies) or failure to recognize underlying bladder dysfunction. Voiding dysfunction or dysfunctional elimination accounts for treatment failures after open or endoscopic correction of VUR. These patients typically have urinary tract infections, incontinence, urgency, frequency, and constipation. Aggressive bathroom management, including strict adherence to voiding and bowel regimens, will often result in resolution of reflux as well as associated lower urinary tract infections. The 2010 AUA Reflux Guidelines recommend management of any suspected bladder/bowel dysfunction, preferably prior to any surgical intervention for VUR [2]. Patients with a previous history of voiding dysfunction must be encouraged to continue their bathroom program preoperatively.

Treatment failure following endoscopic therapy ranges from 7 to 50 % and is dependent upon the technique, VUR grade, and surgeon experience [15]. Success rates for the HIT and double HIT technique approach those following ureteral reimplantation [14] and are currently the most common procedures performed in the USA (Salix Pharmaceuticals, unpublished data).

Though perhaps not a true surgical complication, the development of contralateral VUR after unilateral endoscopic injection may require continued medical or surgical treatment. This finding has been explained on the basis of either occult reflux or even the possibility that high-grade VUR may be a pop-off mechanism for high bladder pressure, which when corrected, may destabilize the contralateral ureter. While many experts in the field consider reflux to be a bilateral process and will correct abnormally appearing contralateral orifices to prevent new reflux from occurring, the true risk benefit has not been determined [16]. In our experience, nearly 15 % of children with unilateral VUR developed contralateral VUR after treatment. By injecting all H2–H3 non-refluxing contralateral ureters, the new VUR rate dropped to 0 % [16].

Finally, previously injected dextranomer/hyaluronic acid copolymer implants may be encountered on computerized tomography as low- or high-density lesions and can be mistaken for calculi. History of vesicoureteral reflux and absence of hydronephrosis as well as hematuria should provide reassurance and prevent inappropriate intervention for misdiagnosed ureteral stones [17] or even bladder tumors [18].

Suggested Follow-Up

Patients should be kept on prophylactic antibiotics until appropriate postoperative studies have been obtained, particularly if there is a history of clinically significant urinary tract infections preoperatively. Renal ultrasound should be obtained 4–6 weeks postoperatively to assess for asymptomatic hydronephrosis. A bladder sonogram will assess the integrity of the implants, and while not directly correlating with the precise position of these implants, retained volume of injection may correlate with success after treatment using the HIT method [19]. The most recent AUA Reflux Guidelines [11] also recommend a postoperative voiding cystourethrogram, but there is wide variability in postoperative imaging dependent upon the individual patient and the surgeon's clinical experience and success rate [13].

Inasmuch as the long-term impact of VUR and renal injury in individual patients is unknown, screening for late-occurring complications of VUR can be performed yearly. Monitoring includes measurement of blood pressure, selective renal sonography, and a urinalysis to access proteinuria, renal growth, hydronephrosis, and infection. Patients with recurrent febrile urinary tract infection after successful endoscopic treatment of VUR should be evaluated for elimination dysfunction and recurrent reflux.

Summary

Endoscopic injection of bulking agents is now recognized as a safe and highly successful minimally invasive alternative to ureteroneocystostomy. The method currently achieving the highest radiographic success rates is the double HIT method,

with results approaching that of ureteral reimplantation. The postoperative febrile UTI rate is at least as low as that following open surgery, making it an excellent alternative to ureteral reimplantation [20]. Progressive ureteral obstruction is a serious complication, and although it occurs in less than 1 % of children, it requires intervention either by ureteral stenting or placement of a nephrostomy tube to achieve renal drainage. Persistent reflux is often managed conservatively, and bowel/bladder dysfunction should be addressed prior to repeating endoscopic injection.

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Chapter 23
Bladder Outlet Injection for Urinary Incontinence

Selcuk Yucel and Linda A. Baker

Abstract Urinary incontinence in children is multifactorial, and thus numerous medical and surgical modalities exist to treat it. In patients with congenital incompetence of the bladder neck/sphincteric mechanism or leak from a continent catheterizable channel, a viable minimally invasive option is cystoscopic-guided injection of bulking agents. In this chapter, indications, surgical techniques, complications, and outcomes of bulking agent injection therapy for urinary incontinence will be discussed.

Keywords Urinary incontinence • Pediatric • Infant • Child • Injection therapy • Bladder outlet • Bladder neck • Bulking agent

Numerous pathological states can lead to urinary incontinence in children. The multifactorial nature of this problem requires both a complete analysis of the contributing factors and a logical approach to correct them.

Factors to consider in the incontinent child include [1]:

- What is the total quantity of urine produced daily? Does the quantity exceed the capacity of the urinary system?
- Is the bladder capable of storing urine?
  - What is the bladder capacity and detrusor compliance? Is there increased bladder contractility, such as in neurogenic bladder, infection, or detrusor hypertrophy?

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  - Is the bladder outlet resistance low, such as an incompetent sphincteric mechanism because of congenital malformation, trauma, iatrogenic injury, or neurogenic deficiency?

- Is the bladder effectively emptying?
  - Is there decreased detrusor contractility, as seen in neurogenic states?
  - Is there increased outlet resistance, such as in urethral strictures, posterior urethral valves, or detrusor-sphincter dyssynergy?

Pediatric urologists are often faced with challenging congenital birth defects in which the incompetence of the bladder neck/sphincteric mechanism causes or contributes to the incontinence. Multiple medical and surgical management options exist, indicating that one simple solution does not exist to cure outlet incompetence. One viable alternative is the injection of bulking agents in the bladder outlet.

Indications and Contraindications

Indications for bladder outlet bulking agents include bladder outlet incompetence with associated urinary incontinence. Specific pathological states with these problems often include neurogenic bladder, cloacal exstrophy, classic bladder exstrophy, epispadias, cecoureterocele, urethral duplication, or ectopic ureter with maldeveloped bladder outlet. In some cases, the bladder outlet incompetence is combined with a deficiency in bladder capacity because of maldevelopment and/or the absence of normal bladder cycling to stimulate bladder growth. Thus, in addition to improving bladder outlet resistance, an additional indication and goal of bladder outlet injection surgery may be to promote bladder growth and increase bladder capacity. A recent review claims that bladder neck injection should be the first-line treatment to increase the bladder outlet resistance in children [2]. More controversial indications include giggle or stress incontinence in children. An extension of this technique has been the injection of leaking catheterizable channels.

Contraindications would include hemodynamic instability or untreated UTI. A relative contraindication is the past history of multiple bladder outlet surgeries, as the success rates are greatly diminished in this population.

Preoperative Investigation

The preoperative assessment of the child incontinent of urine includes a thorough history and physical examination, with attention to voiding and bowel habits. The initial orifice evaluation may include a urinalysis, uroflow, and a postvoid bladder scan. A detailed voiding and elimination diary should be completed, with an

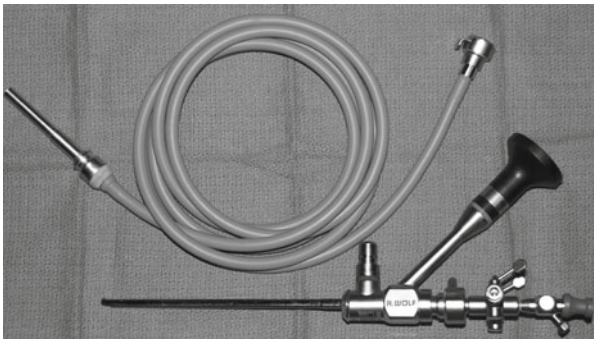

Fig. 23.1 An example of an offset cystoscope. The working channel is straight so that the injection needle is not bent

assessment for vaginal voiding. If indicated, therapy should include behavioral modifications and laxative therapy. Further evaluation is tailored to the considered diagnoses. Videourodynamics is typically necessary to evaluate bladder capacity, bladder compliance, detrusor leak point pressure, and bladder instability. In cases with a high index of suspicion for an anatomical basis for the incontinence, radiological imaging is warranted, often including renal/bladder sonogram, DMSA, and VCUG. Further tests, such as MRI, may be needed to further delineate the anatomy.

Preoperative Patient Preparation

Once cleared for surgery and meeting NPO restrictions, an oral sedative is given to prevent separation anxiety. The physician may choose to give IV antibiotics preoperatively.

Specific Instrumentation

Most cystoscopic suites are equipped with a monitor for video camera imaging, which allow multiple viewers, teaching, optical magnification, and video recording. A fiber-optic xenon light source is also required. Cystoscopic irrigant (sterile normal saline or sterile water) should be warmed to body temperature to diminish hypothermia. Several companies manufacture pediatric endoscopic equipment, including Wolf, Storz/Olympus, and ACMI. Rigid pediatric cystoscopes range from 5 Fr to adult sizes, and the pubertal status of males should be noted to help judge the equipment needed. Pediatric cystoscopes with an offset lens allow straight entry into the working channel for the use of the injection needle (Fig. 23.1). However, a normal cystoscope can also be used by passing the needle from the working channel with some needle bending. Injection needles, ranging from 3 Fr to 5 Fr, can be made of plastic with a metal beveled tip or of complete metal depending on the

manufacturer. The needle selection depends upon the bulking agent used. Some older bulking agents with higher viscosity, such as Teflon and bioglass, required a larger diameter needle and also a gun to accomplish the injection.

The ideal injectable material for the urinary tract is nonmigrating, durable, biocompatible, nontoxic, noncarcinogenic, nonteratogenic, easily injectable, and affordable. The first injectable material used to treat urinary incontinence was Teflon (PTFE-polytetrafluoroethylene) in 1985 [3], but it is now not in use due to risks of distant particle migration and granuloma formation. After Teflon, glutaraldehyde cross-linked bovine collagen (Zyplast, Contingen), silicone particles (polydimethylsiloxane) (Macroplastique), dextranomer particles in 1 % sodium hyaluronan solution (Deflux), synthetic calcium hydroxyapatite particles in glycerine, and sodium carboxymethylcellulose (Coaptite) have been developed for injection.

Transurethral injection of the male bladder outlet is technically easier than the female outlet, primarily due to the differential urethral length. The short female urethra makes stabilizing a cystoscope and simultaneously positioning and injecting the bulking agent somewhat challenging. To address this issue, a non-endoscopic periurethral injection device was created for adult females, called the Zuidex system (Q-Med, Uppsala, Sweden) [4–7]. The Zuidex system consists of a special implacer, which is a device that mounts four 21 G needles and four syringes of Zuidex (gel of dextranomer microspheres and nonanimal stabilized hyaluronic acid (NASHA)). The implacer has four lateral holes for the insertion of four needles. A protective sheath covers the needles during sheath insertion into the urethra. Once in the midurethra, the sheath is retracted, exposing the needles and permitting lateral needle movement. Each needle and syringe is individually positioned submucosally and the Zuidex is injected. One short-term report on three females suggests its usefulness in girls as well [8], but the system has been withdrawn from the market due to its low efficacy and periurethral abscess formation resulting in urethral obstruction requiring multiple surgeries for a satisfactory voiding [9–11]. A recent review has noted that the success rate of a blind midurethral paraurethral bulking agent injection is less than the success rate of cystoscopically guided proximal urethra or bladder neck injection [12].

Operative Technique

Multiple approaches have been described, depending on (1) from where the leakage is occurring (transurethral leak or continent catheterizable stoma leak) and (2) the postsurgical anatomical configuration (open versus closed bladder neck or presence versus absence of continent catheterizable channel). Three basic options include (1) the retrograde transurethral approach, (2) the antegrade approach via a catheterizable channel, or (3) the suprapubic access approach (Figs. 23.2 and 23.3). Perineal paraurethral approaches for transurethral leaking have basically been abandoned.

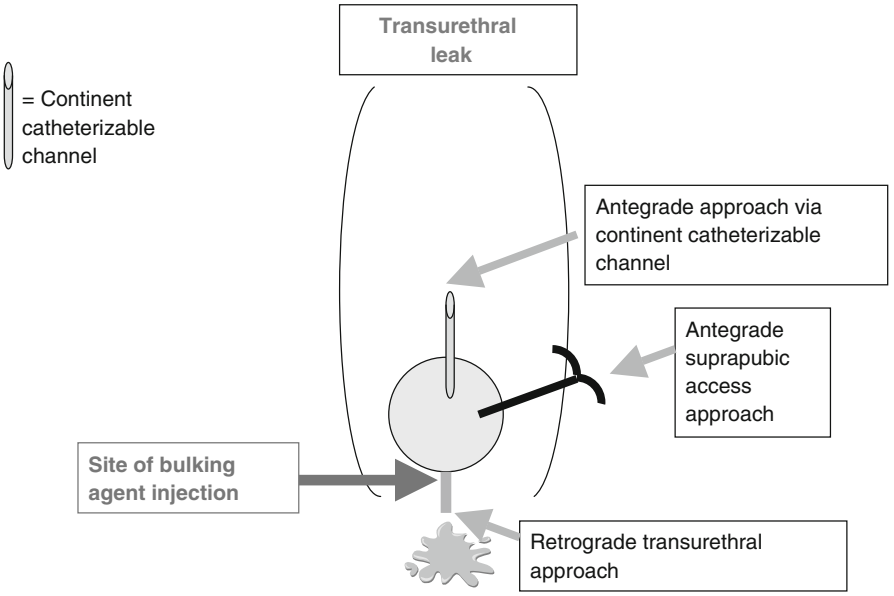

Fig. 23.2 Potential operative approaches to the child with transurethral urinary incontinence due to bladder outlet intrinsic deficiency

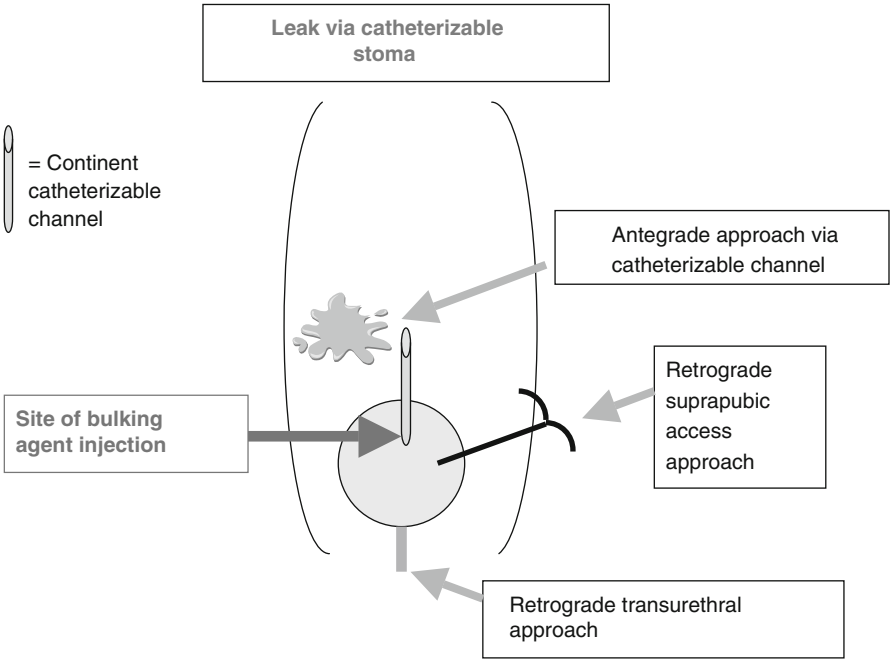

Fig. 23.3 Potential operative approaches to the child with urinary incontinence via catheterizable stoma

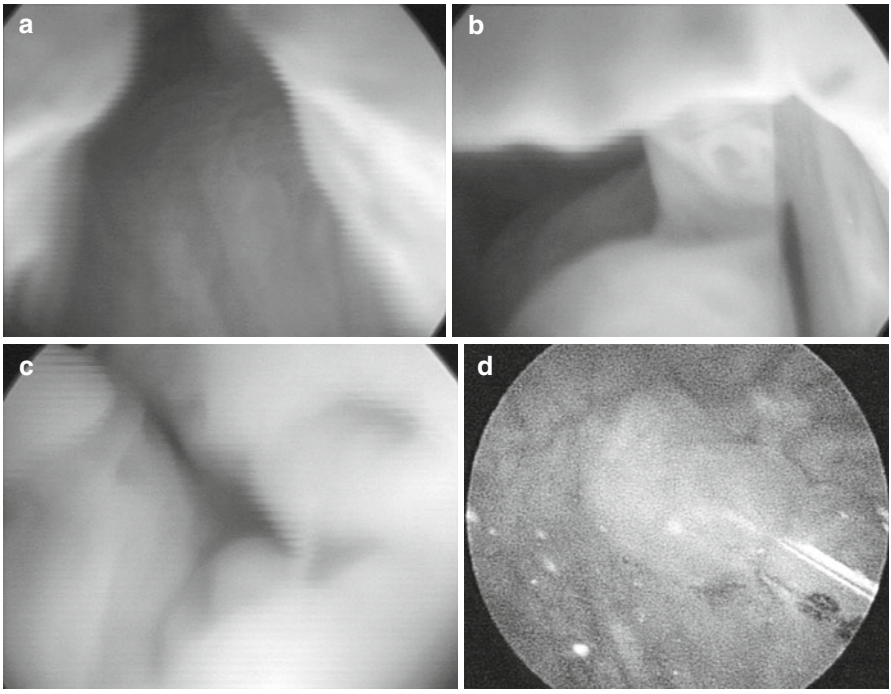

Fig. 23.4 Bladder neck injection for urinary incontinence. (**a**) Transurethral view of incompetent keyhole bladder neck. (**b**) Via the transurethral cystoscope, Deflux was injected into the bladder neck area. (**c**) After transurethral bladder neck injection, the urethral mucosa appears coapted. (**d**) A cystoscope was passed into the appendicovesicostomy, and the bladder neck injection site is viewed

Transurethral Leak

Retrograde Transurethral Approach

The patient is in the dorsal lithotomy position. The lubricated cystoscope is introduced into the urethra and bladder, inspecting for additional anomalies and bladder neck appearance. In males, the needle is inserted submucosally at the level of verumontanum and advanced to the bladder neck [13]. Recently, injection below the verumontanum is also advocated [14]. In females, the scope is positioned in the midurethra, and the needle injection occurs submucosally from bladder neck to the midproximal urethra. Circumferentially, the injection sites may be at two symmetrical points [15], at three points [16], or at multiple points [13]. Regardless of the injection number, the aim is to see complete coaptation of the bladder neck and proximal urethra (Fig. 23.4).

Antegrade Approach

This approach is performed via the continent catheterizable channel. With the patient in the supine position, the lubricated cystoscope is introduced into the catheterizable tunnel with careful manipulation not to harm the continent channel. The bladder neck and posterior urethra are inspected. The injection needle is introduced submucosally at the bladder neck and advanced towards the verumontanum if it can be seen in males and towards the midurethra in females.[12] Injection can be done at two [17], three, or four points to obtain a well-coapted bladder neck.

Antegrade Suprapubic Access Approach

This is an alternative and adjunctive technique to gain temporary suprapubic puncture access to the bladder via a 2 mm laparoscopic trocar. The injection needle is inserted into the laparoscopic trocar, and antegrade bladder neck injection is observed via a cystoscope in the continent catheterizable channel [18]. Injection is done as described above. Since the procedure is done through a laparoscopy port, it has been reported to be performed at the same session with laparoscopic antegrade continence enema with no additional complications [19].

Leak via Catheterizable Channel

Catheterizable Channel Injections

These injections can be approached and performed in a similar fashion as that for transurethral leaking [20]. It is convenient to position the patient in the lithotomy position to permit simultaneous access to the channel and the urethra.

Antegrade Approach via Continent Catheterizable Channel

With the cystoscope in the channel, the walls and opening of the channel into the bladder are inspected. The needle is introduced submucosally 2–3 cm from the orifice and advanced to the orifice at the bladder. Injection is slowly performed until the whole proximal channel wall is elevated including the orifice at the bladder. Injection can be repeated at multiple locations circumferentially until the whole intramural channel is coapted [21].

Retrograde Transurethral Approach

With the cystoscope placed transurethrally, the orifice of the catheterizable channel in the bladder is inspected. The needle is placed into either the patulous channel at 6 o'clock position or a few millimeters below the orifice and advanced further along the intramural channel. Injection is continued until the orifice elevates and is coapted.

Antegrade Suprapubic Access Approach

If a cystoscope cannot be passed via urethra (impassable urethral strictures or closed bladder neck), the suprapubic access approach as described above can be performed temporarily.

Urine should be continuously diverted by an indwelling catheter for 7–14 days postoperatively. However, it should not be placed via the site of injection so as to avoid molding of the injection mound. Thus, a suprapubic tube may be necessary.

Postoperative Management

Bladder outlet injection is an outpatient procedure. Continence is expected to be regained or improved right after the injection, or sometimes it may take a few months until the bladder grows under increased bladder outlet pressure. The length of follow-up after a successful bladder neck injection is variable. Long-term duration of implant is different for every material. The published series with the longest follow-up period reported is 13 years (mean 7 years); they observed the highest recurrence of incontinence within first year [14, 22], particularly in the first 6 months (79 % vs. 56 %) [23]. They concluded that failure after 1 year is significantly related to deterioration of bladder dynamics and requires urodynamic investigations. [24] VCUG can be done to detect de novo VUR after increased bladder outlet resistance in case of febrile UTIs [25].

Complications

Since different materials have different material-specific complications such as migration of implanted particles to lungs and brain for Teflon, teratogenicity of silicone particles, and complete volume loss of collagen, only common complications of bladder neck injection will be covered in this section.

A recent report has demonstrated an interesting complication of submucosal calcifications in 4 of 31 children who underwent bladder neck injection with glutaraldehyde cross-linked collagen as the bulking agent. They found that calcifications at the bladder neck or urethra appear more than 7 years after very high volume injections (mean 21 cc) [26]. A similar complication has been reported from the periurethral injection of hyaluronic acid and dextranomer particles. Severe periurethral abscesses obstructing the bladder outlet have occurred following periurethral injection with Zuidex leading to its withdrawal from the market. However, a similar complication has not been reported yet following bladder neck injections that are performed with cystoscopic guidance [9].

The most important complication is the persistence of incontinence. Bladder neck injection success rates vary from 5 to 50 %, depending on the sex, previous bladder neck surgery, previous bladder augmentation, primary disease-causing incontinence, catheterization, and follow-up period. Previous bladder neck surgery, male sex, no augmentation, bladder exstrophy, and transurethral catheterization seem to have worse outcomes [14, 15, 17, 22, 25].

Catheterizable channels may require additional interventions due to leakage. In 2011, a study of 179 children undergoing continent catheterizable channel creation with a mean 6 years of follow-up shows that 39 % required surgical revision with time, including 8 % who received injection of bulking agent. [27] Few published reports exist on outcomes of injections for catheterizable stomas [20, 21, 25]. In the series, the success rate was 79–86 % at mean follow-up of 12–15 months for leaking catheterizable stomas [21, 28].

Approximately one-third of patients who achieve initial continence with bladder neck injection of bulking agents deteriorate in the first year and become wet [14]. In 2006, a large series demonstrated success rates of 79 % (48 of 61 patients) at 1 month, 56 % (31 of 55) at 6 months, 52 % (24 of 46) at 1 year, 51 % (18 of 35) at 2 years, 52 % (16 of 31) at 3 years, 48 % (12 of 25) at 4 years, 43 % (9 of 21) at 5 years, 36 % (4 of 11) at 6 years, and 40 % (2 of 5). [23] The mechanisms of this initial success with later failure have not been elucidated, but implant displacement with or without volume loss seems conceivable. Another study from the same group notes that no predictors for failure could be detected other than sex, since girls do better than boys. The same study suggests that recurrence of incontinence after 1 year may be related to bladder deterioration [24].

Repeated injections to the bladder neck may cause more difficult open bladder neck surgery. However, a recent study challenges this idea, and 24 out of 89 children with prior bladder neck injections underwent continence surgeries including artificial sphincter, slings, and bladder neck surgeries with no complications. They also note that additional injections are unnecessary after a completely failed bladder injection [29]. Hence, no more than two injections to the bladder neck have been recommended [14].

Bladder neck injection can be an attractive surgical alternative for persistent incontinent cases with prior anti-incontinence surgeries such as bladder neck reconstruction or wraparound sling procedures. Although this procedure is with almost no complication, its efficacy is controversial with around 25 % success rate with a

single injection. Unfortunately, additional injections do not raise the success rate in this specific patient group and are not generally recommended [30, 31].

Urinary retention after transurethral injection or inability to catheterize a channel after stomal injection has not been reported. Postoperatively, bladder compliance and upper tracts should be monitored. Increased bladder outlet resistance can cause vesicoureteral reflux and hydroureteronephrosis [25].

Author's Remarks

The success rates in adults with stress urinary incontinence have not been repeated in children with low bladder outlet resistance. This may be due to the multifactorial nature of incontinence in children with congenital birth defects. In many cases, bladder outlet injection failures are directly related to the anatomical or congenital functional abnormality of the bladder rather than the material injected or the technique preferred. Better success in injecting catheterizable stomas supports this idea although clinical experience is quite limited. However, the literature implies that there are some patients who definitely benefit from bladder neck injections; studies to define these children are warranted. Nevertheless, the long-term studies showing submucosal calcifications with collagen injections clearly warn the surgeons, patients, and families about the possibility of side effects related to bulking agents.

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Chapter 24
Injection Techniques for Bladder and Sphincter

Armando J. Lorenzo and Joseph M. Gleason

Abstract The past decade has witnessed a surge in the use of endoscopic-guided injection of different substances to treat pediatric urological issues, most notable vesicoureteral reflux and urinary incontinence. Two compounds – onabotulinum toxin A and dextranomer/hyaluronic acid – stand out as the most commonly employed ones administered in this "minimally invasive" fashion, often avoiding or delaying further surgical interventions in many patients. Although seemingly simple procedures, attention to indications, contraindications, technique, and monitoring is crucial in order to maximize benefits while avoiding misuse and/or harm. In this chapter we will focus on administration technique in the context of the most common indications, addressing potential pitfalls and complications.

Keywords Endoscopic injection • Bulking agent • Dextranomer/hyaluronic acid • Botulinum toxin • Urinary incontinence • Vesicoureteral reflux

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Why Endourological Techniques for Management of Pathologic Conditions of the Lower Urinary Tract in Children?

Urology has traditionally been an endoscopic specialty, being at the forefront of minimally invasive and diagnostic interventions based on this technology. With scientific advances and miniaturization of equipment, access devices initially designed for adults have been easier to transfer to the pediatric population. Indeed, it is this process that has allowed for easier (nontraumatic) entry through the meatus and urethra, avoiding subsequent problems, most notably iatrogenic trauma and stricture formation. The ultimate testament to this miniaturization process has been the commonplace use of transurethral resection of posterior urethral valves or incision of obstructing ureteroceles in neonates, considered by many the standard of care for the initial management of these conditions with the use of infant resectoscopes.

In many ways, endoscopic techniques represent one of the most common forms of "natural opening" surgery, gaining access to the lower urinary tract via the urethral meatus. Far from being solely employed as a diagnostic intervention (as often seen in older patients), access allows delivery of different substances directly into the bladder neck, trigone, or detrusor muscle, aided by a needle with standardized depth mark(s). As such, endourological access is a means of delivery, rather than a surgical technique per se; the challenge centers on performing the actual administration and the rationale for selecting such intervention over other options. These procedures are commonly shorter in duration and associated with quicker recovery, with the obvious advantage of not generating visible scars. Nevertheless, although appealing in its simplicity and lack of invasiveness, contrast with traditional (open) techniques often demonstrates lower efficacy and – due to their novelty – shorter follow-up.

The *STING* Revolution

With little doubt, pediatric urology grew as a subspecialty with the acceptance of vesicoureteral reflux as an important clinical entity, amenable to surgical correction in order to limit short- and long-term morbidity [1]. This popularization generated a "need" for surgical treatment, questioned by many due to the morbidity of the procedure, particularly for low grades of reflux in otherwise healthy children, thus fueling the role of nonsurgical and less-invasive surgical options. The widespread use of endoscopic injection has its origins on the landmark work by Puri and O'Donnell who pioneered the use of Teflon® as a bulking agent to manage this condition in a minimally invasive fashion [2]. The technique (so-called classic STING)

involved a single submucosal injection at the 6 o'clock position of the ureteral meatus. Although initially met with skepticism and some resistance, a few decades later this delivery modality (with some modifications) has surpassed in popularity other surgical options in many parts of the world. Even though the employed bulking substance has changed, currently heavily favoring dextranomer/hyaluronic acid, the administration principles remain fundamentally unchanged. In addition, the attractiveness of lower surgical morbidity by taking advantage of natural entry points fueled enthusiasm for expanding the application to other conditions. It is probably fair to say that the contemporary success and enthusiasm for endoscopic injection largely rest on this pioneer work.

Basic Principles of Surgical Technique

The "art" of endoscopic treatment heavily weighs on the injection technique rather than access. Cystoscopy is a basic urological skill, and getting to the injection site adds little in terms of additional challenge, except for minor adjustments that are required when employing a straight working channel (angled or offset ocular) scope, as well as negotiating the urethra, of limited caliber and potentially more delicate than in adults. On occasion, entry options may be limited or favored to a catheterizable channel (i.e., Mitrofanoff or Monti-Yang), which needs to be negotiated as gently as possible, and drug delivery adjusted based on the limitations imposed by the different "view" obtained.

The injection technique itself has to be adapted to the indication for surgery and the substance to be delivered. For vesicoureteral reflux, most commonly treated by injection of dextranomer/hyaluronic acid, the compound is precisely placed in a submucosal plane – through one or two injection sites – at the level of the ureteral orifice and intramural ureter. Similarly, in selected cases, this substance can be delivered at the bladder neck/proximal urethra level to create resistance (or "controlled obstruction"), in an attempt to address stress urinary incontinence. In contrast, botulinum toxin is injected at multiple sites in order to cover the muscle mass targeted for temporary paralysis. The latter case is seemingly less impacted by a steep learning curve, yet requires skill avoiding limited visualization as the case progresses due to early injury of large submucosal vessels, as well as good spatial planning in order to evenly distribute the fixed predetermined dose of diluted botulinum toxin throughout the treatment area.

In the following paragraphs, we will address specific issues based on injection sites and pathology, attempting to create a clear distinction between the detrusor muscle, ureterovesical junction, and bladder neck/sphincter. In addition, the authors' preference for endoscopic management is summarized in Tables 24.1, 24.2, and 24.3.

Table 24.1 Subureteric endoscopic injection with bulking agent for treatment of vesicoureteral reflux

Indications
Primary vesicoureteral reflux
Reflux after previous ureteral reimplantation
Contraindications (relative)
Reflux recurrence after previous endoscopic injections (≥2)
Secondary vesicoureteral reflux (neuropathic bladder, posterior urethral valves)
Refluxing obstructed megaureter
Nonfunctioning (refluxing) renal unit
Ectopic ureter (bladder neck)
Active urinary tract infection
Equipment
Straight channel (angled ocular) pediatric rigid cystoscope
Deflux® needle (3.7Fr x 23G × 350 mm) with circular mark 6 mm from the tip
Deflux® gel prefilled syringe (dextranomer microspheres [50 mg/mL] in hyaluronic acid; microsphere range, 80–250 μm with an average size of about 130 μm)
Technical preferences
Perform cystoscopy in "low" lithotomy position, avoiding too much flexion at the hips
Prophylactic IV antibiotics after induction
Urine culture (optional)
Double HIT injection: first, bolus in the intramural aspect of ureter; second, one at 6 o'clock position of the meatus ("classic STING")
Injection done at ~50 % of bladder fill, avoid over-distention
Injection should be done slowly, avoid "pushing" the needle into the tissue, rather relax the scope and needle allowing the agent to favor the submucosal plane
Consider a gentle rectal exam, particularly if there is history of constipation and/or anterior displacement of bladder by distended rectum during cystoscopy
Postoperative management
Procedure done as day surgery, discharge once recovered from anesthetic
Continue antibiotic prophylaxis until first follow-up visit
Avoid constipation (liberal use of PEG or other stool softener)
Reinforce good bladder/voiding habits
Follow-up ultrasound at 6–8 weeks, sooner if complaining of back pain or presents with clinical evidence of pyelonephritis
Postoperative cystogram OPTIONAL, based on parental preference. Support selective cystogram only in cases with recurrent febrile urinary tract infections

Specific Conditions Addressed by Endourological Injection in Children

Vesicoureteral Reflux

Contemporary knowledge on vesicoureteral reflux management is limited and filled with controversies, fuelled by limited data of modest quality [3]. Nevertheless, as previously mentioned, reflux management opened the way for endoscopic drug

Table 24.2 Bladder neck injection with bulking agent for urinary incontinence

Indications
Mild to moderate urinary incontinence due to bladder outlet deficiency
Contraindications (relative)
Lack of improvement after previous bladder neck injections (≥2)
Low compliance/high filling pressure, bladder not responsive to medical therapy
Previous bladder neck procedures (except bladder wall flap-based ones)
Previous lower abdominal procedures that would raise concern for bowel adhesions in suprapubic region (for antegrade technique)
Equipment
Straight channel (angled ocular) pediatric rigid cystoscope
Deflux® needle (3.7Fr x 23G x 350 mm) with circular mark 6 mm from the tip
Deflux® gel prefilled syringe (dextranomer microspheres [50 mg/mL] in hyaluronic acid; microsphere range, 80–250 μm with an average size of about 130 μm)
Large-bore AngioCath, peel-away sheath, and guidewire
5 mm laparoscopic port
Technical preferences (antegrade approach)
Prep genital and lower abdominal region
Prophylactic IV antibiotics after induction
Urine culture
Perform cystoscopy through urethra and over-distend the bladder
Under cystoscopic visualization, advance AngioCath through the abdominal wall, aiming for entry towards the dome of the bladder
Advance guidewire through AngioCath and dilate tract with peel-away sheath, then advance sheath of Step® trocar into bladder over wire, and radially dilate with 5 mm trocar
With CO_2 gas insufflation, perform antegrade submucosal injection of bulking agent at the bladder neck, either two or four quadrants depending on amount of coaptation obtained (1 cc of Deflux® per quadrant)
Place suprapubic catheter
*If patient has a Mitrofanoff or Monti channel, the procedure can be done through it as long as adequate access to bladder neck can be achieved
*Antegrade access may not be a good option in patients with previous augmentation cystoplasty
Postoperative management
Procedure done as day surgery, discharge once recovered from anesthetic
Keep suprapubic catheter to straight drainage for a week or two
If patient is not on clean intermittent catheterization before surgery, use suprapubic tube to measure postvoid residuals

and substance delivery in pediatric urology. Although there has been a progressive transition based on concerns raised by different compounds (i.e., Teflon®, particle distal migration; collagen, poor long-term durability; and polydimethylsiloxane, difficulty injecting the substance), dextranomer/hyaluronic acid has gained wide acceptance and is currently one of the most commonly employed products in many parts of the world. Although at a slight cure rate disadvantage against the gold standard – ureteral reimplantation – success rates have been consistently favorable and high enough to sustain interest and demand for the procedure due to its less-invasive nature [4]. As experience has grown, so have the scope of indications and the severity of reflux approached with endoscopic injection. Indeed, it has been

Table 24.3 Bladder wall botulinum toxin injection for neuropathic dysfunction

Indications
Urinary incontinence due to neuropathic detrusor overactivity
Maximum dose of anticholinergics given without improvement or anticholinergic intolerance
Low capacity, low-compliance bladder with incontinence and/or upper tract deterioration, as an alternative before considering reconstruction (i.e., augmentation cystoplasty)
Contraindications (relative)
Lack of improvement after previous botulinum toxin injection
Evidence of incompetent bladder neck (outlet)
History of adverse reaction to botulinum toxin injection
Equipment
Straight channel (angled ocular) pediatric rigid cystoscope
Deflux® needle (3.7Fr x 23G × 350 mm) with circular mark 6 mm from the tip
Botox® (onabotulinum toxin A) 100 unit vial, diluted in 10 cc of injectable normal saline to a concentration of 10 units/cc. Maximum dose of 10 units/kg up to 300 units
Technical preferences (antegrade approach)
Prophylactic IV antibiotics after induction
Urine culture
Avoid bladder over-distention; perform injections at 50–75 % capacity
If debris is noticed during cystoscopy but urothelium shows mild or no inflammatory changes, proceed with injection after bladder wash with normal saline (1–2 cycles)
Intra-detrusor injections covering the bladder wall, progressing in a stepwise fashion from left to right (using ureteral orifices as a guide), with 4–5 rows of serial injections. Attention should be paid to avoid submucosal vessels as bleeding makes the procedure progressively more difficult
* If patient has a Mitrofanoff or Monti channel, the procedure can be done through it. This is particularly useful in patients with prior bladder neck reconstruction

postulated that the rather benign risk profile and favorable effectiveness challenges the time-honored view of employing antibiotic prophylaxis as the mainstay initial strategy, thus creating a paradigm shift whereby minimally invasive endoscopic intervention is offered soon after diagnosis. Although debatable, the situation highlights the impact of disruptive technology in the management of a disease process [5].

Aside from grade of reflux and the presence of associated abnormalities (such as duplication anomalies, ureteroceles, previous reimplantation, and lower urinary tract dysfunction causing secondary reflux), experience and surgical technique appear to play an important role in successful reflux correction. Undoubtedly, there is an important learning curve. Accurate location and depth of the injection is paramount in bulking the ureter at the level of the orifice and intramural ureter, maximizing the probability of creating an anti-reflux mechanism (Fig. 24.1; see accompanying Video 24.1, Case 1). In addition, the introduction of the so-called double hydrodistention-implantation technique (HIT) – which entails two separate injection sites at the intramural ureter and at the interior aspect of the orifice – has translated into excellent results in some series, seemingly better than single injection STING technique [6]. Cure rates in excess of 90 % reported with this modification have even led many to question the need for routine voiding cystourethrogram

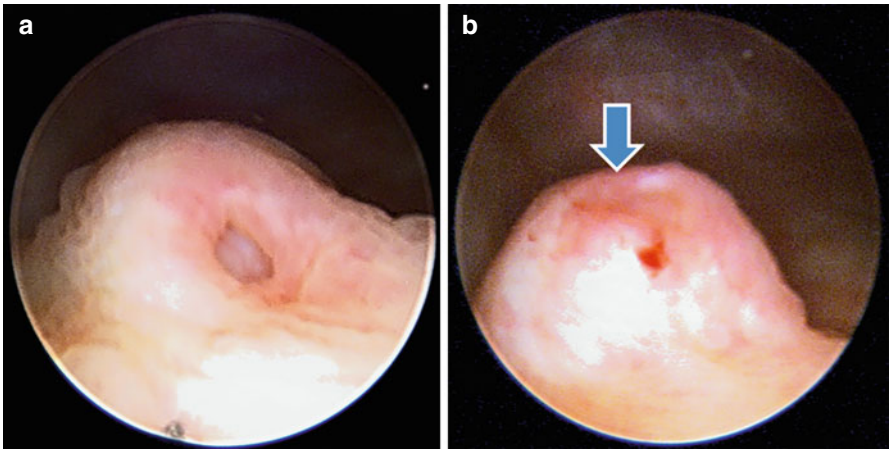

Fig. 24.1 Double HIT technique for endoscopic correction of vesicoureteral reflux. Panel (**a**) shows the "first HIT," deposited in the intramural aspect of the ureter, followed by injection at the 6 o'clock position of the ureteral orifice (**b,** classic STING technique), creating a "volcano" appearance, effectively raising the ureteral orifice (*arrow*)

in treated children, formerly a requisite in many centers due to the novelty of the intervention and the perceived inferior cure rate.

There are three possible causes of failure with endoscopic injections: bolus displacement, loss of volume over time, and extrusion. Following implantation, volume can decrease up to 20 % during the initial tissue response and loss of the injected vehicle molecule. Precise delivery and injection of larger volumes (generally at or above 1 cc, which is the arbitrary amount of dextranomer/hyaluronic acid present in the commercial formulation, Deflux®) helps minimize the occurrence of these scenarios, with an associated small – albeit not insignificant – risk of creating obstruction [7, 8]. As this rare outcome is difficult to predict and not always associated with symptoms, regular monitoring with ultrasound after implantation remains reasonable (Fig. 24.2). Importantly, patients with secondary reflux and underlying anatomical abnormalities may be at higher risk, thus should be considered a relative contraindication for endoscopic injection and trigger diligent postoperative monitoring if done.

Even with a negative cystogram, some children present with subsequent recurrent pyelonephritis, and a subset will experience recurrence of vesicoureteral reflux [9]. Although this can also be seen with more invasive procedures, the situation calls into question long-term cure in a growing child who has a bolus of fixed volume. Ultimately, the lack of long-term data should be taken into account when offering endoscopic injection for reflux, and due consideration should be paid to reevaluating with a cystogram in patients that develop pyelonephritis despite previous reflux resolution. Children found to have recurrent or persistent reflux after endoscopic injection may benefit from a second attempt at correction with this approach, being mindful that additional attempts appear to become increasingly futile, thus shifting the risk/benefit discussion towards alternative surgical interventions.

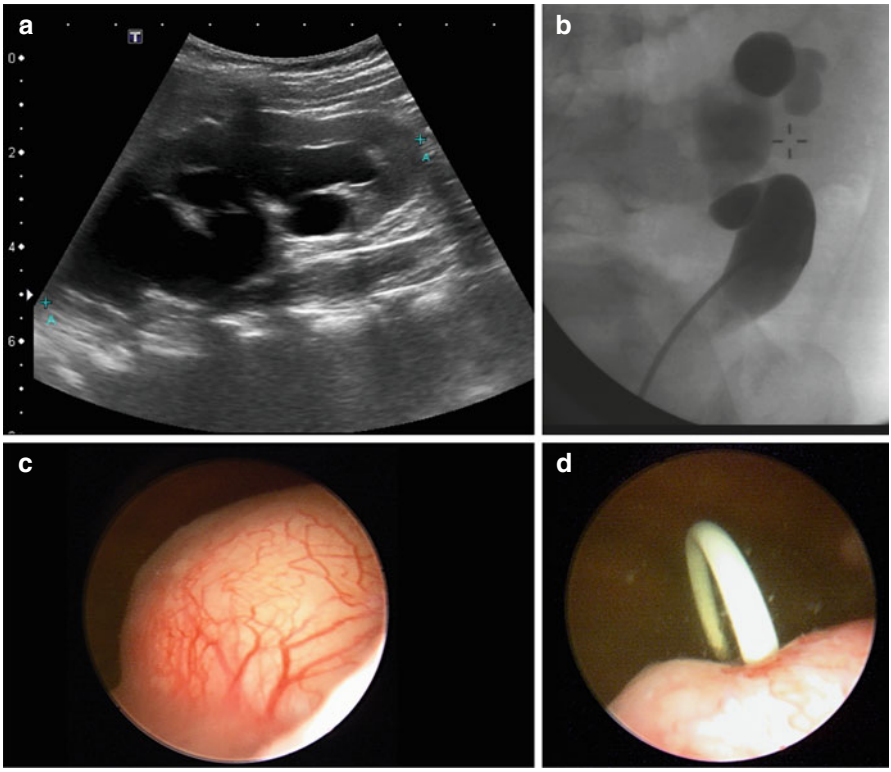

Fig. 24.2 Rare occurrence of obstruction following dextranomer/hyaluronic acid injection in a patient with vesicoureteral reflux. Panel (**a**) demonstrates severe hydronephrosis, with ureteral dilation down to the level of the implant (**b**). This problem was addressed by cystoscopically identifying the bulking agent mound (**c**) and advancing a ureteral stent under fluoroscopic guidance (**d**). The patient experiences resolution of the hydronephrosis following stent removal 6 weeks later

Incontinence Due to Bladder Neck/Sphincter Incompetence

In line with the enthusiasm for use of bulking agents in pediatric patients, and partly based on data from addressing the bladder neck employing similar agents in adults with incontinence, endoscopic interventions have been introduced for management of urinary leakage, particularly for children with neuropathic compromise or previous surgical reconstruction. The main patient populations targeted include children with spinal dysraphism and patients with bladder exstrophy. In addition, the scope has been broadened beyond loss of urine per urethra, also encompassing incontinence experienced through surgically created access channels. These include appendicovesicostomies (Mitrofanoff channel), reconfigured bowel channels (Monti-Yang), and antegrade continence enema accesses (MACE procedure).

The potential for benefit cannot be underestimated, as these children have often undergone major prior procedures or have important comorbidities that make

minimally invasive options appealing. Unfortunately, modest to low success rates have been the norm, particularly following long-term follow-up [10]. Despite these less-than-favorable outcomes, many have proposed that there is little to lose by trying, being a reasonable "first step" before embarking on more invasive interventions. Clearly, this is dependent on many factors, including the underlying bladder dynamics, family and patient expectations, degree of incontinence, and where the leakage is coming from (urethra vs. surgically created channel or both). It is noteworthy that recurrence or worsening incontinence after an attempt at addressing the lower urinary tract outlet or failure to address the problem despite what appeared to be a straightforward uncomplicated intervention should prompt the surgeon to consider hostile bladder pressures and compliance as a potential culprit. In addition, the success of the injection can be adversely impacted by previous surgery to the surgical area (as scar tissue prevents the bulking agent from elevating the submucosal plane), degree of bladder neck incompetence, and the employed approach (transurethral vs. suprapubic access). In that regard, bladder neck reconstructions that generate scar tissue at the very same location where the injection is targeted are bound to make the attempt at bulking the area rather unrewarding. An exception to this rule is prior reconstruction that created a flap-valve mechanism (most notably the Pippi Salle bladder neck procedure), whereby – in the absence of a fistula – injection can be directed at the supple tissue present in the flap itself and provide a reasonable implant. In all cases, a widely patent and patulous bladder neck with effacement that extends into the proximal urethra (including the *verumontanum* in boys) provides little reassurance that enough resistance can be generated to provide continence. Therefore, assessment of this area on a cystogram and during diagnostic cystoscopy is of great value in planning ahead. Lastly, for reasonable candidates, due consideration should be given to deliver the bulking agent through a suprapubic access which avoids instrumentation at the same site of the injection and provides a better view of the bladder neck before and after deposition of the implant [11].

One of the main drawbacks from injection of a bulking agent in the course or entry point of a catheterizable channel [10, 12], or at the level of the bladder neck, is the tissue reaction that can be triggered. Remembering the reported success rates, which are commonly far from ideal and often close to 50 %, it is not unreasonable to consider what to do in case of failure and if this preliminary step is going to create problems in those children that fail. Anecdotally, bladder neck reconstructive interventions after injection have been considered to be more difficult, yet recent data challenges that notion and provides reassurance particularly with the most commonly employed agent, dextranomer/hyaluronic acid [13].

Neuropathic Detrusor Overactivity and Incontinence

It has been known for quite some time now that, in a subset of children, management with anticholinergics and clean intermittent catheterization is not going to render them dry and/or will be associated with progressive upper tract damage.

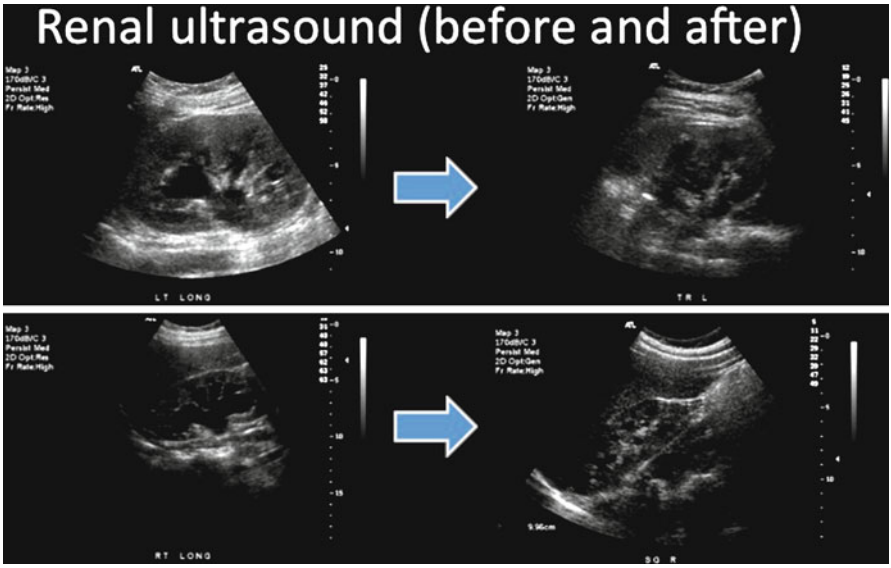

Fig. 24.3 Improvement in upper tract dilation in a child with neuropathic bladder and no evidence of secondary vesicoureteral reflux. Following injection, monitoring ultrasound showed a decrease in bilateral hydroureteronephrosis, which correlated with improved bladder dynamics (enhanced compliance, increase in bladder capacity, and absent detrusor overactivity during filling phase)

Until recently, these children were considered to be good candidates for major reconstruction, often centered on increasing bladder capacity and improving compliance by anastomosis of a detubularized segment of bowel (i.e., augmentation cystoplasty). Although an effective way to deal with the problem at hand, the long-term complications and health concerns are neither minor nor inconsequential [14, 15].

Following experience with adults with neuropathic bladder, endoscopic injection of botulinum toxin has been carefully introduced in the pediatric arena. Currently, this novel strategy has been offered to children who are unable to tolerate anticholinergics (or experience important side effects with dose escalation) as well as those who continue to experience adverse outcomes related to neurogenic detrusor overactivity despite maximal medical therapy. Reported symptomatic and urodynamic improvement rates have been extremely favorable, and side effects are very rare [16]. Aside from patients who have a previously documented adverse reaction to botulinum toxin injection or with an unacceptable anesthetic risk, it is often a good strategy to consider before embarking on more aggressive surgical reconstruction (Fig. 24.3). In addition, injection can often help determine the role of bladder neck incompetence in the urinary incontinence picture. This "therapeutic challenge" can be quite informative, considering that children who continue to leak despite improvement in bladder urodynamic parameters following injection should be considered for concomitant bladder neck procedures, such as a bladder neck sling [17]. An important point when offering botulinum toxin injection is to ensure compliance

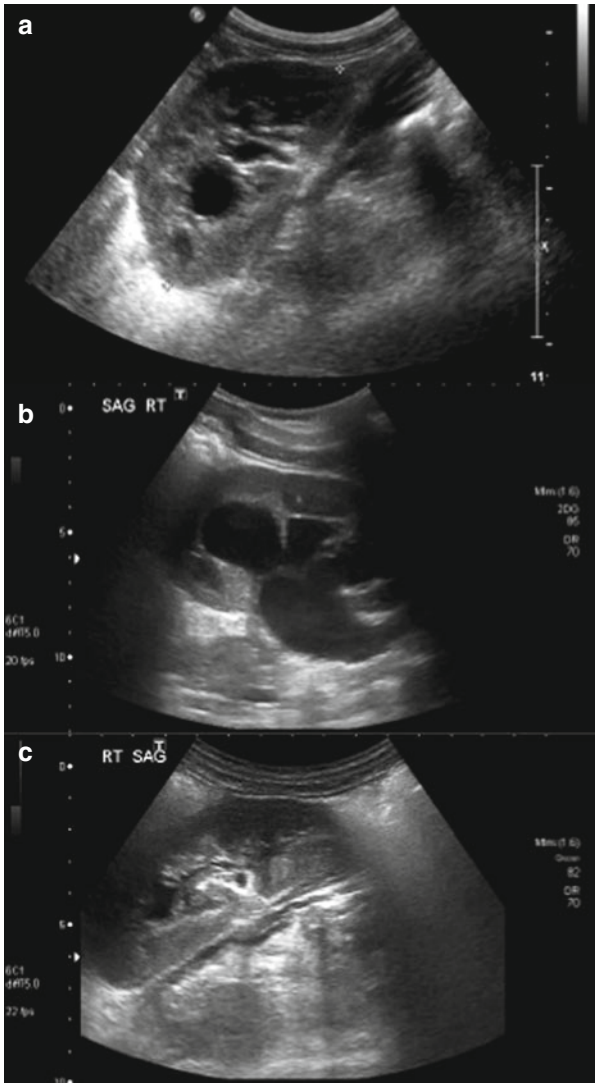

Fig. 24.4 Degree of hydronephrosis before (**a**) and after (**b**) botulinum toxin injection in a teenager that refused regular catheterization following the intervention. Notice dramatic increase in dilation (**b**), associated with doubling of serum creatinine, which rapidly improved after placement of an indwelling catheter (**c**)

with catheterization, as an effective detrusor neuromuscular blockade without effective regular emptying can have serious upper tract deleterious effects (Fig. 24.4).

The procedure itself is rather simple (see accompanying Video 24.2, case 2). The most commonly employed substance, onabotulinum toxin A (Botox®, Allergan, Irvine, CA), is diluted in sterile normal saline at a concentration of 10 units/cc. Based on an empirical dosing scheme of 10 units/kg up to a maximum of 300 units, doses are injected throughout the bladder wall in an intra-detrusor/submucosal location. It is paramount to remember that botulinum toxin formulations are not

comparable in terms of clinical effect and risk of side effects at equal doses, thus use must be based on data relevant to the particular toxin selected for use [18]. The effect of the medication is not permanent, and reinjections are the rule, often at intervals of ~6 months (twice a year). Concerns regarding problems with depth of injection or triggering vesicoureteral reflux if the trigone is injected have been unfounded [19], and thus far, no evidence for tachyphylaxis [20], development of neutralizing antibodies [21], or progressive fibrosis [22] from repeated injections has been consistently reported. The main drawbacks from this intervention are related to costs, demand on resources (operating room), and need for regular anesthetics in children and young adolescents. Indeed, as these patients get older (and particularly in those with a higher sensory level), injection through a flexible cystoscope in the clinic setting may help alleviate some of these concerns and improve efficiency.

Dysfunctional Elimination Syndrome and Detrusor Sphincter Dyssynergia

As a natural next step following the above mentioned experience with botulinum toxin, endoscopic injection has been expanded to the management of non-neuropathic conditions, most notable dysfunctional voiding and difficult to treat non-neurogenic detrusor overactivity. Often down the list in terms of treatment options [23], due to the need for anesthesia and the risk of worsening incontinence or need for catheterization, experience is limited and often anecdotal. The surgical technique is adapted to the source of the problem: bladder neck/sphincter area in children with evidence of true dysfunctional voiding (i.e., triggering pelvic floor/sphincter activity during micturition) and bladder wall in those with urodynamic evidence of significant detrusor overactivity despite optimal pharmacological therapy. Bladder wall administration mimics the technique described above, while the sphincter and bladder neck area are endoscopically injected at three or four quadrants, each injection delivering 25–33 % of the total amount desired to be given. The doses are often lower than for the neuropathic group (~2–4 units/kg), up to a maximum of 100 units for onabotulinum toxin A, and reinjections reserved for those that present with recurrent symptoms, often at longer intervals, or not required at all [24]. In addition, injections in children with predominant complaint of urgency may be theoretically better when delivered at the submucosal level, attempting to address the non-cholinergic aspect of botulinum toxin neurotransmitter blockade (See accompanying Video 24.2, case 2).

Concluding Remarks

There are some evident differences in goal and treatment philosophy with the abovementioned indications. Although all are “minimally invasive,” some aim at permanent deposit of substance to hopefully remain unchanged and undisplaced

after tissue response and remodeling, while the other one is a means of local drug delivery for molecules too large to reach the target organ by mere instillation. Despite this, growing acceptance of endoscopic injection as a viable alternative to managing many lower urinary tract conditions clearly indicates that the future will include expanding strategies based on this technology. Some challenges remain, particularly in terms of more definitive or permanent improvement, higher success rates, and avoidance of need for a general anesthetic. This latter point is particularly worrisome, considering the need for further procedures in many children, due to emerging data raising neurotoxicity concerns in children exposed to anesthetic agents [25]. Ultimately, as with grapple with issues related to success rate and surgical morbidity, long-term monitoring coupled with research for better treatment options not dependent on surgical access to the lower urinary tract [26], as well as dose optimization based on age and underlying pathology, is certainly warranted.

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Chapter 25
Posterior Urethral Valves

Shabnam Undre and Divyesh Y. Desai

Abstract Posterior urethral valves (PUV) remain the most common cause of bladder outflow obstruction in male infants. Initial management involves bladder drainage following which radiological investigations are carried out. We describe our preferred operative technique, primary valve ablation, along with the complications that may be encountered. A check cystoscopy is routinely performed 3 months later at which time a circumcision may be offered.

Keywords Posterior urethral valves • Valve ablation • Antenatal hydronephrosis

Introduction

Posterior urethral valves (PUV) remain the most common cause of bladder outflow obstruction in male infants. The condition has an estimated incidence of 1/4,000–1/5,000 live births. It is a pan-urinary tract disorder with a variable spectrum of severity that can affect both the upper and lower urinary tract [1, 2]. It is one of the most common causes of chronic renal disease in boys.

The advent of antenatal ultrasound screening has dramatically changed the presentation, with more than 50 % of cases being detected on antenatal screening. At our institution, currently more than 90 % of boys with PUV have had the diagnosis suspected antenatally and confirmed in the first week of life. Antenatal scan findings

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may include bilateral or unilateral hydroureteronephrosis in a male child, oligohydramnios, or anhydramnios.

With increasing awareness of this condition and a low threshold for aggressively investigating boys with urinary tract infections, the diagnosis is being made sooner. The advantage is that the potential detrimental effects of obstruction and recurrent urinary infections on the upper and lower urinary tract are minimized following early intervention.

In children who have not had a prenatal diagnosis, the presentation in the neonatal period is usually with symptoms of urinary tract infections, pyrexia, vomiting, poor weight gain, or dry diapers with a poor urinary stream. In the older child, they classically present with difficulty in passing urine, dribbling incontinence, or urinary retention [3, 4].

The initial management on suspecting the diagnosis usually involves draining the bladder preferably by a suprapubic catheter. Alternatively the bladder could be drained via a urethral catheter.

Subsequently radiological investigations are carried out to confirm the diagnosis. These include an ultrasound examination of the urinary tract, a micturating cystourethrogram (VCUG), and an isotope renal scan to assess individual renal function (DMSA or MAG3 isotope scan). The ultrasound will document degree of hydronephrosis, and cortical echogenicity may reflect renal dysplasia. It will also give information about bladder wall thickening and volume. A classic keyhole sign has been described which may be seen [5]. On VCUG vesicoureteric reflux, unilateral or bilateral, may be noted, the posterior urethra will be dilated, and the bladder neck is usually prominent with a caliber change between the dilated posterior urethra and the nondilated anterior urethra (Fig. 25.1).

While the child is on catheter drainage, biochemical parameters are monitored, awaiting stabilization of renal function and achievement of a nadir creatinine level. Following catheterization, the child may go through a phase of post-obstructive diuresis. Therefore, fluid and electrolyte balance should be carefully monitored. Any concurrent urinary tract infection is treated with antibiotics.

In cases where there is significant renal impairment, the input of a pediatric nephrologist is extremely valuable. Following a period of stabilization (usually 10 days to 2 weeks), when the child is hemodynamically and biochemically stable, the obstructing valve membrane is ablated.

Contraindications

To effectively deal with a large majority of infants with posterior urethral valves, appropriate endoscopy equipment must be available.

A relative contraindication to primary valve ablation would include premature infants, in whom the urethra is not of sufficient caliber to accommodate even the smallest of the pediatric endoscopes. The options available in this situation include a temporary diversion with the vesicostomy or, alternatively, one could try and serially dilate up the urethra by passing increasing caliber urethral catheters over a 2- to 4-week period.

In the past, other techniques have been described to ablate the obstructing leaflets. These include a suprapubic transvesical endoscopic approach through the

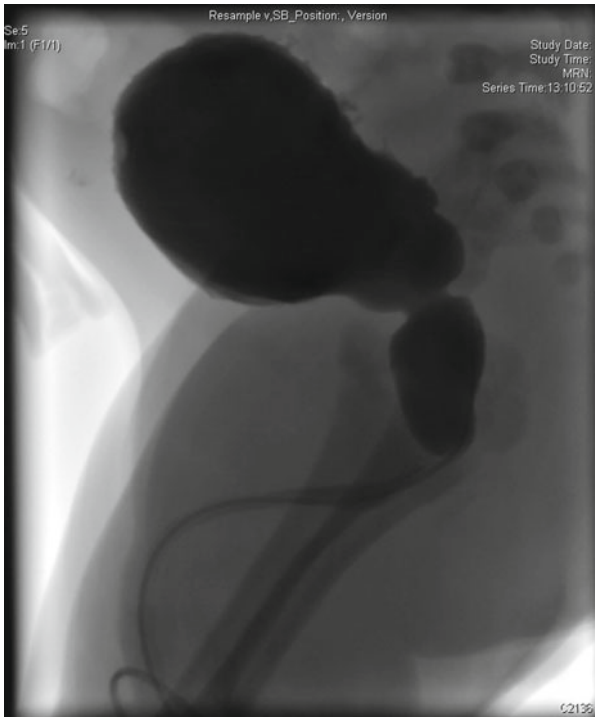

Fig. 25.1 Appearances on micturating cystourethrogram

bladder neck, ablation via a temporary perineal urethrostomy, Fogarty balloon ablation, and using Whitaker's hook. The availability of miniature endoscopes has made these techniques redundant [6, 7].

Preoperative Investigation

Prior to resection of the posterior urethral valve membrane, ensure that the child is hemodynamically and biochemically stable. Specifically, one should check the serum values of creatinine, electrolytes, and acid–base balance to ensure that the child is not acidotic. Radiological confirmation of the diagnosis with ultrasound and MCUG is arranged prior to endoscopy.

Specific Instrumentation (See Figs. 25.2 and 25.3)

Instruments that should be available for valve resection include:

1. Pediatric cystoscope (6 F–7.5 F)
2. Pediatric resectoscope (11 F)
3. Cold knife, bugbee, and diathermy electrodes

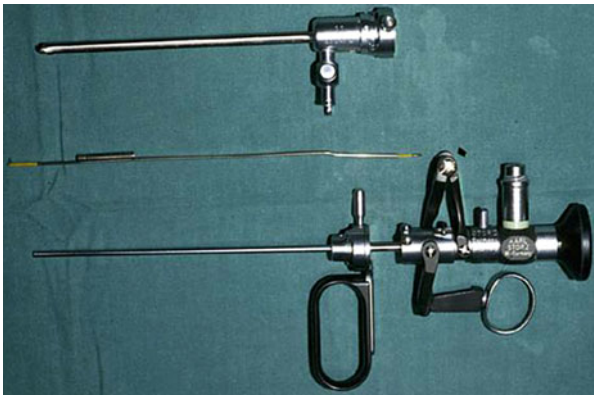

Fig. 25.2 Resectoscope

Fig. 25.3 Cold knife and diathermy hook

Operative Technique

The child is placed in a lithotomy position. Prior to instrumentation, a dose of intravenous antibiotic covering the gram-negative spectrum of organisms is administered (usually gentamicin or amikacin).

The foreskin is separated to retract and visualize the meatal opening. The meatus is calibrated and if necessary serially dilated. An initial diagnostic cystoscopy is performed. I use the 6 F–7.5 F graduated Wolfe cystoscope, which has an inbuilt 30° telescope and a 3/4 F instrument channel.

Following the initial assessment, the valve ablation is carried out using a pediatric 11 Fr resectoscope, with a cold knife or a bugbee electrode. The advantage of the 11 F resectoscope (Storz) is that the tip of the sheath has no bakelite beak and is thus less traumatic and easier to introduce.

In situations where the neonatal urethra is too small to accommodate the resectoscope, the membrane can be ablated using the 7.5 F cystoscope and a 3 F bugbee electrode using a diathermy current.

My preference is to use a cold blade (sickle blade) to cut valve membrane at the 5 o'clock, 7 o'clock, and 12 o'clock positions. There may be some bleeding

encountered following the incision, which usually resolves spontaneously on passing a urethral catheter. (See the technique demonstrated in accompanying Video 25.1.)

Following satisfactory ablation of the valve membrane, a urethral catheter is placed in the bladder, and the suprapubic catheter (if present) is removed. Postoperatively the urethral catheter is left on drainage for a period of 24–48 h and removed.

Following removal of the urethral catheter, urine output is monitored by assessing and weighing diapers and, if possible, observing the urinary stream. Plasma creatinine value is monitored and checked prior to discharge.

The child is usually discharged on prophylactic antibiotics (trimethoprim 2 mg/kg once a day). Follow-up is planned in 3 months time, with repeat radiological investigations which include ultrasound, VCUG, and assessment of renal function with a DMSA or MAG 3 isotope renography.

During this admission, the child will also have a check cystoscopy to ensure adequacy of the valve ablation, and consideration may be given to performing a circumcision.

Complications

With miniaturization of the endoscopes, complications directly related to the procedure are uncommon. Potential complications associated with the procedure include:

1. Bleeding: This could be either the result of overzealous meatal dilatation resulting in a tear or occasionally one can encounter bleeding from the resected valve membrane, particularly with a cold knife incision technique.
2. Infection: It is prudent to ensure that any intervention is covered with broad-spectrum parental antibiotics.
3. Damage to external sphincter: An uncommon complication when the procedure is carefully performed and the landmarks are well visualized and identified.
4. Urethral stricture: This is likely to be associated with diathermy ablation of posterior urethral valves. The incidence is increased if the urethra remains dry in the immediate post-resection period. It can also occur with prolonged instrumentation particularly where the endoscope is a tight fit in the neonatal urethra.
5. Meatal stenosis: This occurs following forced meatal dilation to accommodate oversized instruments.
6. Incomplete resection: When using bugbee or diathermy electrodes, it is safer to err on the side of caution as overzealous diathermy causes greater damage to the neonatal urethra. It is our policy to reevaluate all boys 3 months after initial valve ablation with a repeat VCUG as well as a check cystoscopy. Any residual valvular obstruction is ablated at the second sitting.

Follow-Up

At our institution following the second check cystoscopy, the patients are followed up closely by the nephrologists and also in a dedicated posterior urethral valve clinic. The protocol includes regular evaluation of both upper and lower urinary tract anatomy and function along with periodic monitoring of renal function. GFR estimation is carried out after 1 year of age and videourodynamics performed at age 5 years.

The incidence of renal and bladder dysfunction varies, and a recent systematic review by Hennus et al. confirmed these findings. They found that only the nadir creatinine was a predictor of renal dysfunction [8].

Conclusions

Primary valve ablation is the preferred modality of treatment at our institution. It is physiological as it allows the bladder to continue cycling. The miniaturization of pediatric endoscopes allows for majority of valves to be ablated primarily. During the past 5 years, all boys with PUV have had the obstructing membrane primarily ablated at our institute following a period of temporary drainage.

In premature babies the urethra may not accommodate the smallest cystoscope, and catheter drainage (replaced twice weekly with increasing caliber) may be required for a few weeks before ablation can be safely performed.

The disadvantage of ablating the valve with smaller endoscopes is that once you have a bugbee catheter in the instrument channel, the flow of irrigation fluid is significantly reduced. It is important to ensure adequate visualization of landmarks to minimize complications.

Check cystoscopy within 3 months of primary valve ablation ensures adequacy of treatment and allows residual obstruction to be treated early. Significant complications like urinary incontinence due to sphincter damage are uncommon, and ensuring good visualization of important landmarks during the procedure will minimize problems.

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Chapter 26
Endoscopic Management of Ureteroceles and Syringoceles

Paul F. Austin

Abstract There are several options for surgical management of ureteroceles, and current management involves a selective approach. This chapter will focus on the indications for endoscopic treatment of ureteroceles. The techniques used for endoscopic management are highlighted in the chapter and accompanying video as well as the necessary instruments and tools for pediatric endoscopy. Key points for endoscopic management of ureteroceles in infants and children to avoid complications and comorbidities are noted. Finally, the endoscopic management of syringoceles will be similarly addressed.

Keywords Child • Endoscopy • Infant • Treatment outcome • Ureterocele/diagnosis/surgery/*therapy

Introduction

Ureteroceles and syringoceles are congenital abnormalities that represent ballooning or dilated extensions of the ureter and bulbourethral gland duct (Cowper's duct), respectively. These abnormalities may cause blockage of the urinary tract or impairment of urine flow that results in urinary tract infections, pain, and other lower urinary tract symptoms. Since syringoceles occur infrequently, our primary focus will address endoscopic treatment of ureteroceles, although the treatment principles are similar.

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Indications/Contraindications

Surgical treatment for ureteroceles is selective and individualized [1, 2]. Multiple factors determine the role and method of intervention [3]. A key determinant of treatment is the anatomic location of the ureterocele. If the ureterocele is located entirely within the bladder or intravesical, endoscopic treatment is the most accepted and definitive form of treatment. In contrast, endoscopic treatment of ectopic ureteroceles (e.g., ureteroceles with a portion of their submucosal wall at the bladder neck or extension into the urethra) is not generally a definitive form of therapy. There is a role, however, for endoscopic treatment for ectopic ureteroceles particularly in a child who requires decompression in the setting of urosepsis or azotemia with bladder outlet obstruction.

The majority of ureteroceles present antenatally, and although treatment is based on the anatomic location of the ureterocele, other factors play a role in determining intervention including renal function, ureteral duplication, and the presence of vesicoureteral reflux. If there is poor renal function in the ureterocele moiety, an upper tract surgical approach may be taken (e.g., upper pole partial nephroureterectomy or "simplified approach"). Observation may also be adequate with poor renal function particularly if there is a multicystic, dysplastic kidney associated with the ureterocele and absent or low-grade vesicoureteral reflux [4]. If vesicoureteral reflux is present at high grades or bilaterally, there is a high likelihood that surgical treatment will involve lower tract reconstruction [5].

Depending on the circumstances dictating an upper or lower tract approach, the surgical management is varied and can be addressed endoscopically, open surgery, laparoscopically, or a combination [2, 6–8].

Preoperative Investigations and Preparation

Children presenting with ureteroceles will commonly present with either a history of antenatal hydronephrosis or a history of a urinary tract infection. These clinical scenarios will generate a series of radiologic tests to determine renal function, drainage of the urinary tract, presence of ureteral duplication, and presence of vesicoureteral reflux. Three tests are commonly obtained and include 1) renal and bladder ultrasonography, 2) micturition cystourethrogram, and 3) diuretic nuclear renal scan. These tests will provide information on the cystic appearance of the urinary tract, presence of vesicoureteral reflux, and renal function and drainage, respectively. Alternatively, magnetic resonance urography can be ordered to detect renal function and delineate anatomy, particularly with ureteral ectopia [9].

After proper assessment of the urinary tract, patients should be placed on antibiotic prophylaxis in the presence of vesicoureteral reflux or obstruction. We also obtain a urine specimen 5–7 days prior to the planned procedure to rule out any active infection.

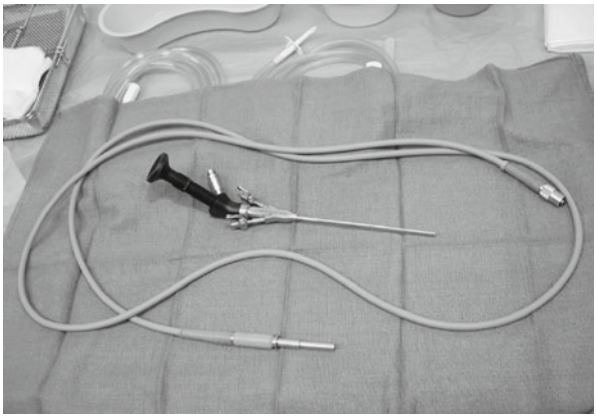

Fig. 26.1 Pediatric/infant offset cystoscope

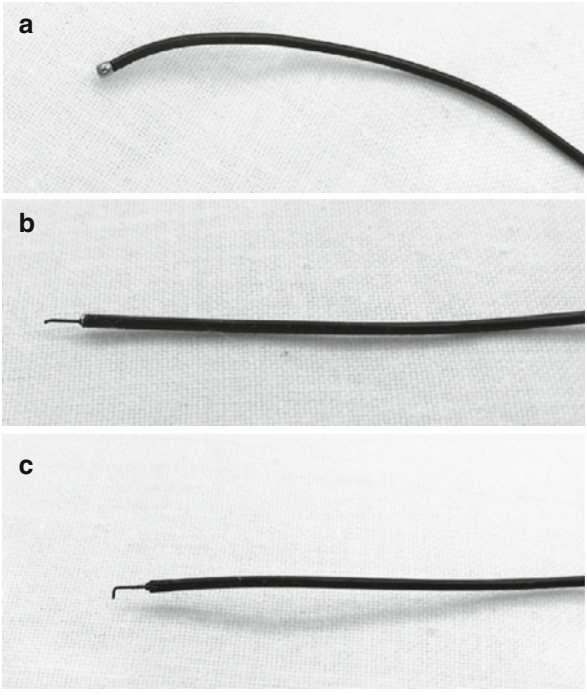

Fig. 26.2 A variety of probes are used for endoscopic treatment of ureteroceles and syringoceles. (**a**) Bugbee-type probe. (**b**) Needle-type probe. (**c**) Right-angle-type probe

Specific Instrumentation

Small endoscopic instrumentation is paramount in treating pediatric patients. A variety of scopes should be available depending on the age of child. We commonly use either an eight French cystoscope or a 9.5 French offset cystoscope with a five French working port (Fig. 26.1). There are a variety of probes that may be used to puncture or incise the ureterocele depending on the surgeon's preference (Fig. 26.2). These probes commonly involve electrocautery current to incise the tissue, but utilization of laser energy [10] may be substituted.

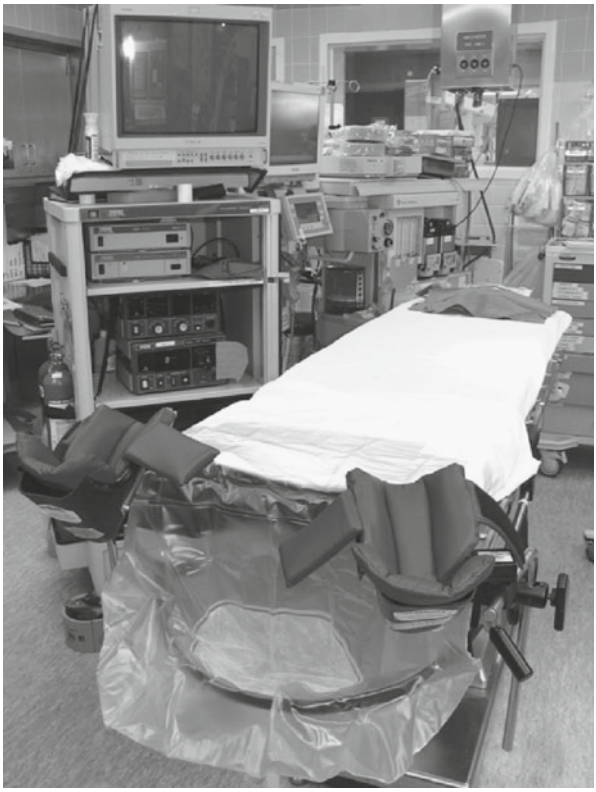

Fig. 26.3 Pediatric endoscopic table with pediatric-size stirrups

Operative Technique

For infants and small children, a gel roll or towel roll underneath the legs is adequate to elevate the lower extremities in a lithotomy position. The legs will need to be secured to the table with tape to prevent any slippage. Accordingly, the skin will need protection with gauze or a small towel. Pediatric-size stirrups or candy canes may be used for toddlers and older children (Fig. 26.3). Lastly, it is important to calibrate and dilate the urethra with sounds or bougies to accommodate the pediatric cystoscope and avoid trauma to the urethra. It is rarely necessary to perform a meatotomy to allow passage of the pediatric-size cystoscopes.

Ureterocele

During cystourethroscopy, it is important to view the urethral anatomy and bladder anatomy with the bladder empty and full. This avoids effacement or compression of the ureterocele when the bladder is distended. Maneuvers to distend the ureterocele

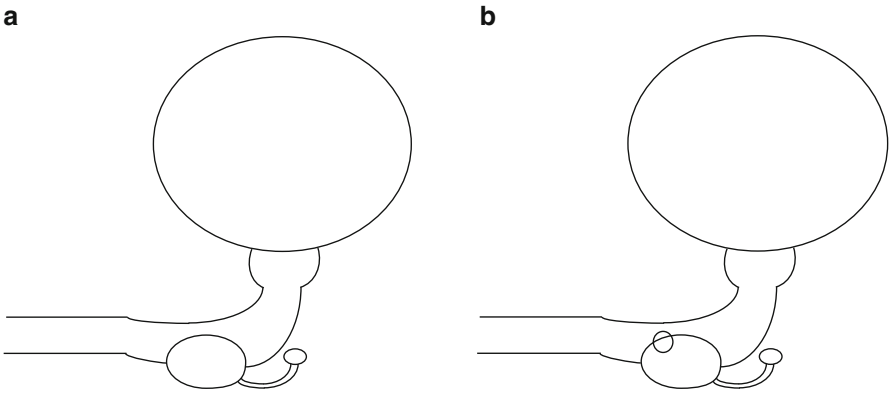

Fig. 26.4 Simple classification of types of syringoceles (Cowper's duct cysts). (**a**) Closed type. (**b**) Open type

may be helpful such as manually compressing the ipsilateral flank. As demonstrated in the accompanying video, we make a small incision or puncture near the base of the ureterocele. This incision site theoretically allows the superior tissue to serve as a "flap-valve" mechanism preventing iatrogenic vesicoureteral reflux. Adequate decompression of the ureterocele is the goal of endoscopic treatment of ureteroceles, but an overaggressive incision or puncture will result in an increased chance vesicoureteral reflux (Video 26.1).

Syringocele

We find the classification that differentiates syringoceles as either open or closed useful in the planning for endoscopic treatment [11] (Fig. 26.4). The closed-type syringocele may be incised for decompression using the same probes utilized for treatment of ureteroceles as described above. Open-type syringoceles may be unroofed by either employing a right-angle probe with cystoscopy or using an infant resectoscope.

Postoperative Management

We do not typically employ any drainage after endoscopic treatment of ureteroceles. Children are placed on antibiotic prophylaxis and are followed up in the clinic with ultrasonography to document decompression. A micturition cystourethrogram is obtained to rule out iatrogenic vesicoureteral reflux. When evidence of decompression is verified and vesicoureteral reflux is excluded, antibiotic prophylaxis is stopped. Further follow-up is performed with ultrasonography and clinical assessment accordingly.

Complications

There are few complications encountered with endoscopic treatment of ureteroceles; however, like all endoscopic procedures, there are risks of trauma to the urethra with resultant iatrogenic stricture. Proper pediatric instrumentation obviates this risk. Creation of iatrogenic vesicoureteral reflux is well known with endoscopic treatment of ureteroceles particularly with ectopic ureteroceles. Judicious use of incising or puncturing the intravesical ureterocele minimizes this risk.

Author's Remarks

Endoscopic treatment of ureteroceles and syringoceles is relatively straightforward. Judging the appropriate incision site from large ectopic ureteroceles can be challenging. Key points for treating ureteroceles include avoiding overaggressive puncture causing iatrogenic reflux and utilization of infant-size endoscopic equipment and probes.

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Chapter 27
Extracorporeal Shock Wave Lithotripsy: Principles of Fragmentation Techniques

Hasan Serkan Dogan and Serdar Tekgul

Abstract Shock wave lithotripsy constitutes the majority of treatment options of stone disease in children. Its safety and efficacy has been proven by the clinical experience accumulated till today. The technique and indications have been well established, and the success and complication rates have been described in details. Today, authors are able to develop nomograms to predict the outcomes. These nomograms showed that young age, small stone burden, single stone, absence of previous intervention history, and pelvic/upper ureteral location are favorable factors, whereas stone size is the most important factor for complication occurrence. Therefore, appropriate patient selection is important to minimize the failure rates and adverse effects.

Keywords Urinary • Calculi • Stone • Treatment • Children • Pediatric • Shock wave lithotripsy • Minimally invasive

History

The first report on the use of shock wave lithotripsy (SWL) in children was published after a sufficient experience on adults [1]. As the feasibility was shown, a number of series have been reported in the literature, and SWL has gained a wide acceptance as a first-line therapeutic modality in children.

Technique

Technique is similar as in adults. However, the need for anesthesia is the main difference in order to stabilize the child and stone. The procedure in children may

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be performed under sedation or general anesthesia with laryngeal mask or intubation [2–5] by both gated (synchronized lithotripsy shocks to the patient's electrocardiogram reading) and ungated technique [6] and can be safely applied even in infants [7].

Focusing may be done by both fluoroscopy and ultrasonography. Ultrasonography guided focusing of the stone thereby decreases the radiation exposure. The number of shocks per session is between 1,800 and 2,000, and the power is set between 14 and 21 kV [8]. Although it may be increased on demand, children, most of the time, require less number of shock waves and lower energy for stone fragmentation when compared to adults [9].

The deleterious effect of SWL were found to be closely related with the power and number of shocks applied. However, the alterations in renal function usually are transient and return to baseline values within 15 days [10]. Therefore, the interval between two sessions should be at least 2 weeks. The concerns about the long-term effects of SWL on renal function were tried to be clarified by several studies. In summary, these studies on pediatric SWL and other minimally invasive treatment approaches were not found to cause adverse renal morphologic or functional alteration [11, 12].

Indication

Today, most of the pediatric stone disease patients are treated by SWL. Primary treatment option in patients with pelvic stones <20 mm, lower pole calyceal stone <10 mm, and proximal ureter stones is SWL [13]. Moreover, SWL may be the secondary treatment option for bigger stones and distal ureteric stones with the need of more sessions and additional procedures or may be used as a complementary modality to other minimally invasive techniques.

Contraindication

Presence of active urinary tract infection (UTI), obstruction distal to the stone, and uncontrolled coagulation disorders are contraindications of SWL. The presence of UTI can be screened with routine preoperative urinalysis and culture. However, the fact that urethral urine can be sterile in case of a completely obstructed collecting system should be taken into account. The obstruction distal to the targeted stone can be relieved by ureteral stent placement. In this context, the role of preoperative stenting can be discussed. Although effect on stone-free rates is unclear, in cases of solitary kidneys and/or large stone burden, preoperative stenting will be beneficial in terms of preventing complications related to obstruction.

Success

Success of SWL depends on many factors. Stone size is one of the most important prognostic factors [14–16]. Regardless of the location, the stone-free rates for <1 cm, 1–2 cm, >2 cm, and overall were reported as nearly 90, 80, 60, and 80 %, respectively, and the need for additional sessions increases with the increase in stone size [13]. However, some authors reported that up to 30 mm, stone-free rate is not affected by the stone size [17, 18]. Moreover, even staghorn calculi have been treated with a success rate of 80 % [19–21]. Though, authors recommend ureteral stenting prior to SWL in order to decrease the complication rates and hospital stay [20].

Location is another prognostic factor for success. Except for the lower pole location, calyceal, pelvic, and proximal ureteral stones respond well to SWL with a 90 % of clearance. However, SWL treatment has a 50–60 % success rate for lower pole stones probably depending on the infundibulopelvic anatomy [22–25], and although it is difficult to describe a cutoff, stones >10–15 mm in lower pole may be better treated by alternative modalities. However, a recent study reports favorable results for lower calyceal stones up to 20 mm [26]. Stones in congenitally anomalous kidneys have also been treated with acceptable success rates [27]. For ureteric stones, one study reported an overall stone-free rate of 91 % (proximal, 94 %; middle, 94 %; and distal, 89 %) with a 49 % retreatment rate [28]. However, today URS with its higher efficacy quotient is the first treatment option particularly for distal ureteric stones.

Cystine, brushite (dicalcium phosphate dihydrate), and whewellite (calcium oxalate monohydrate) are known to respond to ESWL poorly [29], thus these patients should better be directed to alternative treatment options. Also, patients with metabolic or anatomic abnormalities have a lower stone-free rate (31.7 % vs. 69.4 %) [30]. Therefore, determination, treatment, and follow-up of underlying causative factors are important. In patients with radiolucent stones which probably are uric acid stones, combination of SWL with medical treatment (alkalinization alone or in combination with allopurinol) may result favorable outcome [31]. The attenuation of stone on noncontrast computerized tomography has also been shown to have a significant impact on stone-free rates. When patients were stratified into two groups (less than 1,000 and 1,000 HU or greater), the shock wave lithotripsy success rate was 77 and 33 %, respectively [32].

Age is not a limiting factor for SWL application. As previously mentioned, even infants can be treated safely [7, 33]. Stone-free rates seem to be better [34], and stone-free state is achieved more quickly [35] with the decreasing age which might be attributed to softer stone composition, smaller relative stone volume, increased ureteral compliance to accommodate stone fragments, and smaller body volume to facilitate shock transmission [36]. Another important issue in pediatric urolithiasis is to obtain the real stone-free state. The fragments following a treatment modality can behave as a nidus for future stone formation. Supporting this hypothesis, in one study, it was shown that 69 % of children with residual

Table 27.1 Review of the literature on complications of SWL in children [39]

Complications	Incidence (%)
Renal colic	2–19
Fever	0.8–8.5
Urinary tract infection	1.2–7.7
Stone street	1.1–17.4
Urethral stone	<1
Dermal ecchymosis/bruises	0–100
Perirenal hematoma	<1
Enteric wall hematoma	<1
Gross hematuria	11.3
Hemoptysis	3 case reports

fragments (RF) (≤5 mm) following SWL had adverse clinical outcome (symptoms or residual fragment growth) which is significantly higher than the stone-free subjects, and RF growth was found to be significantly associated with the presence of metabolic disorders [37].

As the experience increases and the data accumulate, development of a nomogram for children has been possible. A recent nomogram study showed that younger age (<5 years), smaller stone burden (<1 cm), absence of previous stone treatment history, single stone, and pelvis or upper ureter location (in girls) were favorable prognostic factors for successful outcome [38]. This nomogram can be used for patient selection and parental information purposes.

Complications

Complications of SWL in children are generally minor and self limiting [39]. These complications are given in Table 27.1. Renal colic is one of the most frequent complications because of the shock waves passing through the tissues and passage of the stone fragments. Pain can be treated with analgesics, though obstruction should be evaluated by imaging modalities. Preoperative sterile urine is recommended before SWL. However, even with sterile urine, fever and urinary tract infection can occur. It may be because of the microorganisms harbored within the stone or infected urine captured in a collecting system obstructed by the stone. Persisting postoperative fever should be evaluated seriously and treated promptly. Formation of stone street in the lower ureter is closely related with preoperative stone size [40]. It should be followed up with serial imaging studies. Preoperative ureteral stenting may be prophylactic in children with large stone burden. It usually resolves spontaneously; ureterorenoscopy is therapeutic if conservative measures fail. Dermal ecchymosis is an expected complication; however, more significant effects of shock waves on kidney (subcapsular hematoma) and intestine (enteric wall hematoma) are rare and managed conservatively. Piezoelectric lithotripsy was shown to cause less renal injury when compared to electrohydraulic and electromagnetic lithotriptors [41]. Macroscopic hematuria is again a transient postoperative complication which is

managed conservatively. Hemoptysis, an unexpected pulmonary complication secondary to lung contusion, has been fortunately reported only three times in the literature [39]. This complication may be avoided by shielding the lungs with shock-absorbing material or altering the mode of mechanical ventilation during the procedure.

Conclusion

In the era of minimally invasive surgical approaches to stone disease, SWL is the primary treatment option for most of the children. Recent data and experience revealed its safety and efficacy. Complications are mostly minor and self limiting. Appropriate patient selection is important to minimize the failure rates and adverse effects.

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Chapter 28
Pediatric Percutaneous Nephrolithotomy

Prasad P. Godbole

Abstract Advances in endourological techniques and their successful application in adult renal calculi over the last 30 years have led to a dramatic move from open surgery to minimally invasive techniques for pediatric urolithiasis. This chapter will focus on percutaneous nephrolithotomy (PCNL) and the tips and tricks in the procedure to achieve a successful outcome.

Keywords Pediatric • Urolithiasis • Percutaneous nephrolithotomy • Mini perc

Introduction

Pediatric urolithiasis has an overall incidence of 1–2 % of that observed in the adult population [1]. Urolithiasis is an endemic disease in the stone belt across the Middle East and Asian subcontinent. One report suggests an incidence of 17 % among children in Turkey [2]. Stones may be calcium oxalate stones which are reported to be the most frequent [3] or noncalcium-containing stones.

Over the last three decades with the successful results in the minimally invasive management of adult renal stones, there has been a shift from historical open surgery in children [4] to a minimally invasive approach. The minimally invasive techniques include extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), and ureteroscopy (URS).

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This chapter will describe the technique of PCNL the authors favor in management of pediatric urolithiasis.

Indications and Contraindications

Most children are suitable for PCNL irrespective of size/habitus (obesity) or abnormalities of the curvature of the spine (scoliosis).

The main indications for PCNL may be classified as:

1. *Stone size and location*
   (a) Staghorn calculus
   (b) Multiple stones
   (c) Renal pelvic stone >2 cm
   (d) Lower pole >1 cm
   (e) Stone surrounding a foreign body
2. *Anatomy*
   (a) Stone secondary to a UPJ obstruction
   (b) Infundibular stenosis
   (c) Stone within a calyceal diverticulum

The main contraindications are:

1. Uncontrolled hypertension
2. Active sepsis
3. Coagulopathies

Preoperative Workup

The preoperative workup prior to a PCNL consists of determination of the size, number, location of the stones, anatomical configuration of the kidney, and the renal function.

The authors prefer the following workup:

1. Plain X-ray KUB and renal ultrasound: Studies have shown that a combination of these two will detect up to 90 % of stones [5].
2. DMSA: This gives information about the function of the kidney.
3. An IVU may be used in some cases to determine the anatomy of the collecting system or where there is a strong index of suspicion of renal tract calculi not evident on the plain X-ray or ultrasound.

4. In selected cases only, an unenhanced spiral CT scan (the gold standard for diagnosing renal tract calculi in adults) may be considered.
5. Baseline blood hematology and biochemistry (FBC, creatinine, and electrolytes) and a group and save.
6. A "spot" urine may be analyzed for metabolic analysis instead of the 24-h urine collection [6]. Where possible, the retrieved calculus should be sent for stone chemical analysis.
7. Within 24 h of the surgery, the child should have another plain X-ray KUB and renal ultrasound scan to reconfirm location and number of calculi.

The Team

One of the most important requirements for a successful PCNL is the presence of a regular team who undertakes these procedures. In our institute, we have two pediatric urologists, two interventional pediatric radiologists, two pediatric anesthetists, and a pool of nursing staff who perform the PCNL. Our experience has shown that working as a team makes it more efficient and safe. A radiographer is also required for the procedure.

Instrumentation

For a PCNL, there is general equipment that is required and specific instrumentation for the PCNL. It is important to have all the instrumentation available to allow a choice of which instruments to use depending on the nature of the stone.

The General Equipment Requirements

1. A fluoroscopy machine (C-arm) with monitor.
2. A camera stack system: In our institute we have the benefit of OR-1 which allows for movement of multiple monitors to achieve the best ergonomic layout for a minimally invasive procedure.
3. A general instrument trolley.
4. Portable US machine.
5. Omnipaque mixed with normal saline (50:50).
6. Surgical table that allows screening.

Specific PCNL Requirements

Preliminary Ureteric Catheterization

1. Cystoscope
2. Ureteric catheter
3. Foley catheter
4. Adhesive tape

Puncture and Access Tract

1. Nephrostomy drape.
2. Needle: Kellett needle or similar puncture needle. The authors prefer a smaller gauge "skater" needle (Angiotech) for the puncture.
3. Dilators: Alken telescopic dilators or balloon dilators.
4. Guidewires: Straight and J tip guidewires and hydrophilic guidewires.
5. Sheath: Amplatz sheath 24 or 26 or mini-perc sheath 15 or 16 French.

Stone Fragmentation/Retrieval

1. Nephroscope
2. Ultrasonic lithotripter
3. Swiss lithoclast
4. Laser (Ho: YAG) with different size fibers
5. Stone retrieval basket (nitinol basket)
6. Forceps
7. Flexible cystoscope

Post Retrieval

Nephrostomy drainage tube with bag

Operative Technique

The operating room layout is depicted in Fig. 28.1 for a left PCNL.

The authors prefer to use the mini-perc system which in our experience (unpublished) appears to be safer and allows for repeated punctures without significant extravasation of contrast. This is demonstrated in the accompanying video.

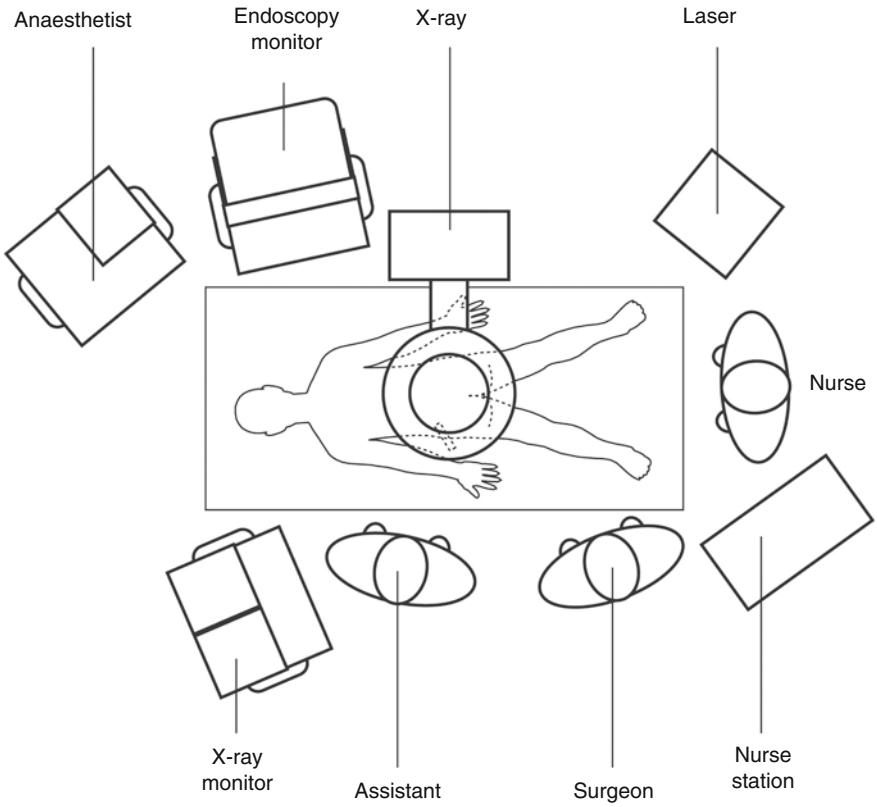

Fig. 28.1 The layout and positioning of personnel and equipment in the operating suite for a left PCNL

Anesthesia

General anesthesia with endotracheal intubation and muscle relaxation

Preoperative Antibiotics

We prefer an aminoglycoside such as gentamicin at induction; however, local microbiology guidance with antibiotic prophylaxis should be used at induction.

Preliminary Ureteric Catheterization

With the patient in lithotomy position, a cystoscopy is performed, and under screening control, the ureteric catheter is positioned just in the region of the pelvis.

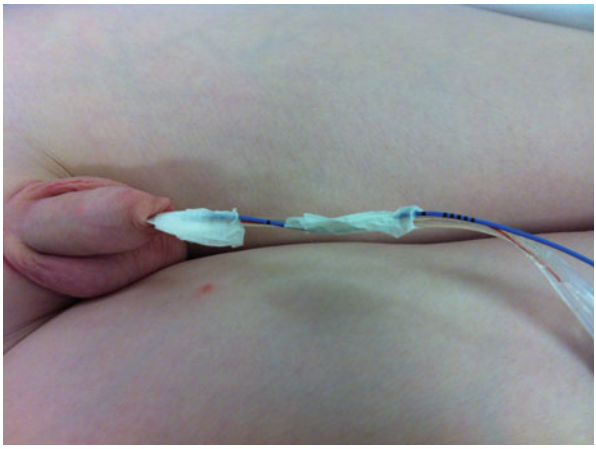

Fig. 28.2 The Foley catheter and ureteric catheter in place and anchored with adhesive tape

Tip: Positioning at this position allows for distention of the collecting system with saline if ultrasound-guided puncture is contemplated.

Once the ureteric catheter is positioned, a Foley catheter (size 8 or 10 Fr depending on age of the child) is inserted, and the ureteric catheter is fixed to the Foley catheter using the adhesive tape. This prevents the ureteric catheter being displaced (Fig. 28.2).

After securing the ureteric catheter, the patient is transferred across to the trolley. The operating table is then padded with appropriate supports for the chest and the pelvis with plenty of warming mattresses and absorbent sheets, as during the procedure, there is a risk that the child may get cold despite warmed saline irrigation.

Position

The patient is placed in the prone position (Fig. 28.3) with appropriate support as described. In this case, a small rolled towel is placed below the left side to raise this by a 30–45° angle. This allows the posterior lower pole calyx to rotate into an end-on position.

Puncture

Depending on the surgeon's preference, the puncture can be performed either by ultrasound guidance or fluoroscopic guidance. It is important to perform a retrograde study via the ureteric catheter to ascertain the calyceal anatomy and hence the best site to puncture to obtain complete stone clearance. In most cases, we perform a lower pole posterior calyx puncture.

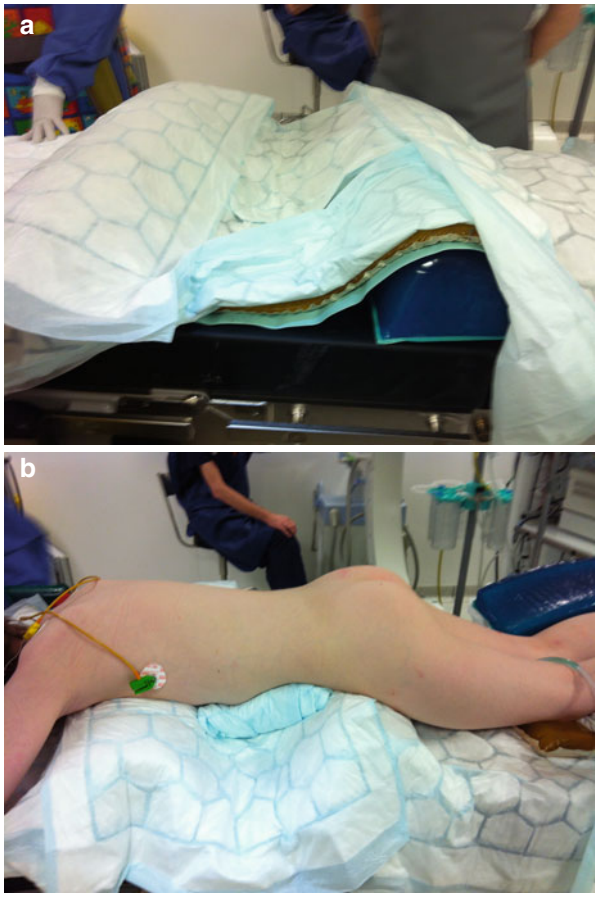

Fig. 28.3 (**a**–**b**) Patient in prone position: note the warming mattress and bolsters to achieve the correct position with slight elevation of the left side for a left PCNL

Prior to the puncture, the assistant injects a saline methylene blue combination (100 ml saline and few drops methylene blue to make it light blue) via the ureteric catheter to distend the collecting system. The puncture is then performed. Removal of the stillette of the needle will reveal blue-colored saline dripping out of the needle confirming its position within the collecting system. A further contrast study with saline and omnipaque will confirm the position of the needle in relation to the punctured calyx.

Dilatation and Access Tract

Following puncture of the collecting system, a straight or J tip guidewire is inserted into the system. Wherever possible, it is important to try and maneuver the guidewire down the ureter to prevent its accidental displacement. However in some cases, coiling of the guidewire within the collecting system may be inevitable.

A skin incision is made to enable dilatation over the guidewire. The skin incision needs to be in the appropriate width depending on the size of the Amplatz sheath to be used.

The tract is dilated with an 8 Fr dilator. Following this, the authors prefer to use the Alken telescopic dilators to the size required. A useful tip is to dilate by one size over the size of the Amplatz to be used and then remove the last dilator. This allows easy placement of the Amplatz sheath. The entire dilatation is monitored by fluoroscopy.

Stone Fragmentation/Retrieval

Once the Amplatz sheath is introduced, the nephroscope is introduced, and saline irrigation commenced. Careful rotating movement of the sheath allows the sheath to be maneuvered in different directions to explore the different calyces.

Once the stone is visualized, fragmentation may be undertaken by several techniques – lithoclast, laser, or ultrasound. Choice of technique depends on personal preference and size of the Amplatz sheath.

Tip: Occasionally, some calyces especially the upper and middle pole posterior calyces may be difficult to negotiate with the Amplatz sheath. In these instances, using a flexible cystoscope may enable the calyx to be entered, and using a laser or nitinol basket, the stone may be fragmented and grasped and retrieved.

If there are multiple stones in various calyces, more than one puncture may be required to obtain complete clearance.

Clearance is confirmed both by ultrasound and fluoroscopically.

Once the procedure is completed, the Amplatz sheath is removed, and a nephrostomy is inserted over the guidewire. The size of the nephrostomy can vary from 6 Fr to 24 Fr depending on the need for drainage and tamponade. We use an 8 Fr nephrostomy as standard. Recently, a tubeless PCNL has demonstrated similar results [6]. The Foley catheter and ureteric catheter are removed at the end of the procedure.

Postoperative Management

Analgesia: In most cases, we give a single bolus of opiates during recovery and then oral analgesia.

Diet: The child is allowed to eat and drink as soon as he/she recovers.

Nephrostomy: Is clamped at 24 h and removed at 36 h if the child remains asymptomatic.

Antibiotics: Oral antibiotics (we prefer co-amoxiclav) are prescribed for 1 week followed by antibiotic prophylaxis till stone-free.

Imaging: All children are followed up at 3 months with an ultrasound and plain X-ray KUB.

Complications

1. Failed puncture.
2. Bleeding: This is the most common complication [7]. Although most of the bleeding is venous and stops spontaneously, in cases of excessive bleeding, the Amplatz sheath should be removed, and a tamponading nephrostomy should be inserted.
3. Residual calculi: These may require further PCNL or ESWL.
4. Renal parenchymal injury: This usually heals with adequate drainage via the nephrostomy.
5. Sepsis: Sepsis is unusual and resolves with systemic antibiotics.
6. Injury to adjacent organs: Although rare, injury to the colon during puncture has been described [7].

Conclusion

For a successful PCNL, the essential requirements are a well-organized team and joint working with an experienced surgeon and uroradiologist. In most cases, success of PCNL in obtaining complete stone clearance should be about 90 %. It is important to note that there is a learning curve for PCNL, and in the initial stages, it is useful to have an experienced surgeon as a preceptor.

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Chapter 29
Ureteroscopy for Urinary Calculi

Hasan Serkan Dogan and Serdar Tekgul

Abstract The incidence of pediatric urinary stone disease is increasing due to the environmental conditions in association with the improving health services and diagnostic modalities. The technological advancements provided more durable, flexible, and small caliber instruments. With the accumulated experience in adults, the treatment choice in pediatric urinary stone disease also shifted to endourological approaches. Ureteroscopy is one of the most important endourological choices of treatment. Technique is similar as in adults. However, having and using the appropriate-sized instruments is important as well as being experienced. In patients with proper indication who were treated by proper endourological principles, both semirigid and flexible ureteroscopy have very high rates of success with minimal complications.

Keywords Urinary • Stone • Pediatric • Ureter • Ureteroscope • Semirigid • Flexible • Technique

Introduction

Urinary stone disease is an important health problem for some geographical areas of the world such as Middle East, North Africa, and South Asia [1, 2]. However, the incidence is increasing in other parts of the world such as North America where pediatric stone disease was known to be a rare event [3, 4]. The incidence is reported to be increasing in white race, children older than 9 years, and girls [5].

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Urinary stone disease in children most of the times is a result of metabolic alterations causing supersaturation of urinary solutes, decrease in crystallization inhibitors, and changes in urinary pH. Other etiological factors can be listed as infections, anatomic abnormalities, diet and fluid intake, and use of some medications [6]. Therefore, children with diagnosis of stone disease deserve a detailed evaluation including physical examination, imaging modalities, urinalysis and culture, blood chemistry, and measurement of urinary electrolytes and end product as oxalate, citrate, and cystine. These evaluations should be completed with the analysis of the stone composition in order to manage the medical treatment. The stones can be obtained by interventional treatment modalities those mostly composed of minimally invasive techniques such as extracorporeal shock wave lithotripsy, rigid or flexible ureterorenoscopy, percutaneous nephrolithotomy, and in a limited number of patients laparoscopic approach. In the era of modern endourological surgeries, open surgery for stone disease in children is an exceedingly rare requirement particularly in children with severe orthopedic problems or in very young ages with large stones and congenital abnormality which should be repaired concomitantly.

Ureterorenoscopy is one of the most frequently utilized techniques for treatment of ureteric stones. In EAU guidelines on Pediatric Urology, URS is recommended as the primary treatment option for lower ureteric stones [7].

History

Although a case of pediatric ureteroscopy was reported in 1988 [8], the first series were published in 1990 by two different authors in the same volume of Journal of Urology [9, 10]. With the understanding of the feasibility of URS even with adult instruments, the use of this technique has gained a wide acceptance. This positive motivation lead to the invention of small caliber and flexible instruments, and these advancements led the surgeons to perform more cases. Today, any location in the ureter and kidney became accessible and treatable by intraluminal endourological techniques.

Indications

The pediatric extracorporeal shock wave lithotripsy (SWL) studies revealed that the pediatric ureter is at least as efficient as the adults' for transporting stone fragments [11]. However, Van Savage et al. showed that ureteral stones greater than or equal to 4 mm in children are less likely to pass spontaneously and will need intervention [12] which reflects the daily practice. Hence, in pediatric population, the main indication for ureteroscopy is the presence of stone especially in the distal ureter with a level 1a of evidence [7, 13, 14]. URS with semirigid instruments can also be performed for middle and proximal ureteral [15] and with flexible instruments for

calyceal and intrarenal stones [16–18]. In addition, ureteroscopy will provide the diagnosis and treatment of rare renal and ureteral pathologies (i.e., fibroepithelial polyps) [19]. For stones larger than 2 cm, laparoscopic or open surgery may be feasible options.

Preoperative Preparation

Presentation tends to be age-dependent, with symptoms such as flank pain and hematuria being more common in older children, whereas nonspecific symptoms (e.g., irritability, vomiting) are common in very young children. In most of the times, a simple abdominal flat plate X-ray combined with ultrasonography is very effective for detecting the stones in the urinary tract. In doubtful cases, noncontrast helical CT with very high sensitivity and specificity will help the diagnosis especially in ureteral stones [20]. Intravenous urography is rarely used in children.

Emergency ureterolithotripsy is very rarely indicated, and most of the time it is performed under elective situations. Although the children with stone disease should undergo detailed urinary and serum investigations, for operative purposes, no detailed serum chemistry is needed unless the disease is bilateral. As in all endourological interventions, preoperative urine should be sterile. In patients with infected urine, appropriate treatment should be given preoperatively. A repeat imaging with a plain X-ray with ultrasonography will be beneficial within the preoperative 24 h to assess the final location of the stone or evaluate the possibility of spontaneous passage in order to prevent an unnecessary session under anesthesia.

Instruments

Minimum requirements for an uneventful surgery are composed of the following instruments:

- Surgical table allowing lithotomy position and permitting fluoroscopy
- Endovision system
- Cystoscope and ureteroscope (rigid, semirigid, or flexible)
- Guidewires (PTFE coated and hydrophilic)
- Ureteral catheters and double J stents
- Dilatators (coaxial or balloon)
- Lithotriptor (Ho: YAG laser or pneumatic)
- Graspers and baskets
- Irrigation system and fluid (normal saline)
- Ureteral access sheath, nitinol tipless basket
- Contrast agent (diluted with normal saline 1:1)

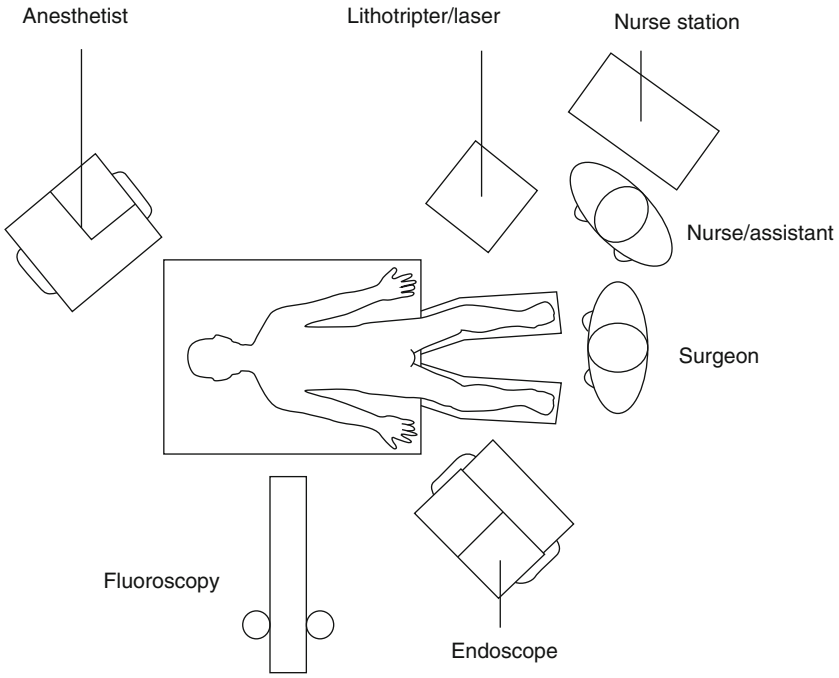

Fig. 29.1 Schematic diagram showing the positions of the surgical team, equipments and the patient (Modified with permission from Lopez and Duffy [34])

Technique: Tricks and Challenging Cases

Operation is performed under general anesthesia and in lithotomy position. In patients with preoperative sterile urine, single dose intravenous antibiotic (i.e., cephalosporin) should be given during induction of the anesthesia. The table and leg support should be able to make modification in the position that sometimes contralateral leg might be flattened to provide a wide range of movement for ureteroscope (Fig. 29.1).

Cystoscopy is done to evaluate the bladder and ureteral orifices and place the guidewire into the ureter. The placement of guidewire should be done under scopic guidance to ensure the correct localization of the wire and to observe in order to prevent unintentionally pushing the stone upwards. (**Trick**: *If PTFE-coated guidewire does not pass proximal to the stone, a hydrophilic guidewire may be tried to be inserted; if this also fails, then leave the guidewire as close as possible to the stone.*)

The choice of caliber of ureteroscope is important. A large ureteroscope will provide a good flow of irrigation fluid and good vision with an increased risk of tissue injury. A fine ureteroscope facilitates entry to the ureter without dilatation and postoperative stent [21, 22], whereas vision might be problematic. Use of instruments $\leq$8 F is safe, and our experience showed that use of semirigid instruments

larger than 8 F is more prone to postoperative complications. A recent study revealed that in children younger than 3 years old, mini-ureteroscope of 4.5 F caliber, the success rate was higher [23].

After the placement of the guidewire, the ureteroscope is inserted through the urethra into the ureter following the lumen of ureter beneath the guidewire. This approach will elevate the guidewire to widen the ureter orifice as a tent and will ease the entrance. (**Trick**: *Especially for the stones located more proximally, it can be difficult to reach the stone. In this case, a second guidewire may be inserted within the ureteroscope so as to straighten the ureter.* **Trick**: *If entry to the ureter without dilation manipulations is difficult, first hydrodilatation of the ureteral orifice can be tried* [24]; *whenever ureter is entered, active squeezing of the hand pump should be stopped in order not to push back the stone. If hydrodilatation is not effective, balloon or coaxial dilatation may be used.* **Trick**: *If it is impossible to get into the ureter, then a double J stent can be placed to have passive dilatation, and a second session 2–4 weeks later can be tried* [25]. **Trick:** *In patients with a history of cross-trigonal ureteral reimplantation, an angled hydrophilic guidewire can be tried, or suprapubic placement of a guidewire through a puncture needle under direct transvesical endoscopic vision can be helpful, or a flexible cystoscope can be used for guidewire insertion.*)

As the stone is reached, disintegration should be done preferably by laser source. Ho: YAG laser is advantageous over pneumatic lithotriptors because of its lesser pushing effect on stone and lower thermal and mechanical injury risk to the surrounding tissue. The power of Ho: YAG laser is usually set at 1–1.5 J and 5–8 pulses/s. The stone will be squeezed gently between the tip of the fiber and ureteral wall. The tip of the fiber should be placed on top of the stone and not in the middle. Fragmentation would be carried on until the particles become as smaller as the tip of the laser fiber that passes spontaneously with no need to extract. (**Trick**: *The tip must be >1 mm away from the urothelium or the guidewire during activation of the laser pulses, as the depth of thermal injury is 0.5–1 mm.* **Trick:** *Irrigation pump should be used cautiously.*)

If stones are fragmented with laser energy as small as the tip of the fiber, there is no need to extract them. However, if extraction of the stones is required, grasping forceps should be preferred. If basket will be used, fragments should not be larger than the tip of the ureteroscope. (**Trick**: *If a large stone is entrapped within the basket and if the surgeon can't release the stone from the basket, no attempt must be done to take out the basket in a locked position on a large stone which can cause ureteral avulsion. Instead, a 200-μm fiber can be inserted through the working channel of ureteroscope, and the stone can be fragmented at the hazard of the basket; alternatively, the handle of the basket can be disjoined, the ureteroscope can be taken out when the basket is left in the ureter, then the ureter is entered again, and stone in the locked basket can be fragmented and the basket can be released.)*

During the operation, fluoroscopy should be used with consideration to the radiation exposure since it was shown that children receive significant radiation throughout the procedure significantly more than conventional X-rays, cystography, or computerized tomography [26]. Therefore, the surgeon should try his/her best to

apply the as low as reasonably achievable (ALARA) principles (to maximize the source to skin distance, proper dose rate setting, judicious use of fluoroscopy, clear communication) during minimally invasive stone surgeries.

If the operation was straightforward with no complication, surgery may be ended without any ureteral stent. However, a ureteral catheter or a DJS with a string exiting from the urethra for a couple of days may be used. There is no consensus on the use of postoperative stenting. In complicated cases with a suspicion of injury or in cases with a high stone burden which necessitated different manipulations during the surgery, a DJS may be left in place for 2–4 weeks for resolution of local edema.

In the postoperative period, the urethral catheter – if placed – may be pulled out at the end of 24 h. Patient and the parents should be informed about the possible voiding problems due to the presence of the internal stent and early infectious complications. Routine analgesic for 2–3 days may be prescribed. Collecting and filtering the voided urine should be suggested to obtain the stone fragments to get analysis of the stone composition.

Success

Success of the surgery is universally over 90 % in one session regardless of the location and composition of the stone and approximates to 100 % with auxiliary procedures such as SWL and repeat ureteroscopy [6, 27].

Complications

Despite the minimally invasive nature of the endoscopic surgery, it is not without complications. A multi-institutional study on the factors affecting the complication rates showed that while operative time, age, institutional experience, orifice dilation, stenting, and stone burden were statistically significant on univariate analysis, operative time was the only statistically significant parameter on multivariate analysis [27]. Complications can be categorized as intraoperative, early postoperative, and late postoperative complications those listed in Table 29.1 [28].

The intraoperative complications are stone migration, ureteral wall injury and avulsion, inability to access the stone, and conversion to open surgery. The stone migration can be prevented by use of fluoroscopy during retrograde guidewire placement, cautious use of irrigation fluid, gentle compression of the stone between the probe and ureteral wall during lithotripsy, and use of cone baskets if available. When proximal migration of the stone to the kidney occurs, retrograde intrarenal surgery or postoperative SWL may be the option. The ureteral wall injury most of the time is secondary to the unintentional contact of the probe to the ureteral mucosa. These injuries are generally minor and heal without any problem with postprocedural stenting. However, hemorrhage due to the injury can disturb the vision and

Table 29.1 Review of the literature on complications of semirigid ureteroscopy for treatment of ureteral calculi [28]

Complications	Incidence (%)
Intraoperative	
Stone migration	<6
Ureteral perforation	<6
Inability to access the stone/place guidewire	<12
Conversion to open surgery	<13
Early postoperative	
Hematuria	<27
Infectious complications	<4
Stent migration	<4
Late postoperative	
Stricture	<2
Vesicoureteral reflux	0–17[a]

[a]The real incidence is not known and thought to be negligible since in most of the studies it is reported very rarely and with a very low incidence. Only one study reported VUR of low grade in 17 % of children [29]

complicate the operation. Inability to access the stone rarely may happen due to the local edematous tissue reaction just distal to the location of the stone. In these cases, making forceful maneuvers to reach the stone may traumatize the tissue that probably became edematous and fragile. Instead, placing a ureteral stent over a guidewire will solve the problem and dilate the ureter which will facilitate an easier second session. If stent placement fails, laparoscopic or open surgery might be indicated. The avulsion of the ureter may be the most devastating complication which occurs secondary to several factors. The forceful attempts to enter into the ureter with an inappropriate size instrument cause the avulsion of the distal end. Lithotripsy under a blurred vision situation may be the other cause. But the most important mistake which should be avoided is capturing a larger stone than the ureteral orifice with a basket and trying to retrieve it in an en bloc fashion. The open surgery as ureteroneocystostomy or ureteroureterostomy is the only option to repair the avulsion of the distal part of the ureter or a short segment. However, in very rare occasions, mostly due to the inappropriate use of basket, a very long segment can be traumatized that primary anastomosis is impossible. In this case, placing a nephrostomy tube and planning further complicated solutions (ileal ureter, autotransplantation) for ureteral replacement may be necessary.

The early postoperative complications are hematuria, urinary tract infection, and stent migration. Postoperative minimal hematuria might be normal, but gross hematuria following a straightforward surgery is unexpected. Hematuria most of the times is transient and self-limited, and conservative measures such as forced diuresis are sufficient. In cases with sustaining postoperative gross hematuria over 24 h which might need intervention should be followed up with imaging and blood count studies. Stent migration may happen when a ureteral stent of improper length was used which can be avoided by using the simple 10+ age (in cm) formula [30]. Urinary tract infection (UTI) with or without fever is not a rare event. As in adults, it is obligatory to have sterile urine preoperatively, though in cases whose urine

cannot be free of infection, surgery should be performed under appropriate antibiotic treatment. However, obeying the antiseptic conditions during the surgery is the main principal, because many instruments are used during the surgery which can easily be contaminated with contact to the non-sterile environment.

Late postoperative complications are stricture of the any segment in the ureter and vesicoureteral reflux (VUR). Both complications may be attributed to the use of inappropriate size instruments, traumatic surgery, active dilatation of the orifice, and healing with fibrosis of the mucosal tears because of the presence of stone and the surgical injury itself. Even after an uncomplicated surgery, periodic imaging with ultrasonography is recommended. The obstructive hydronephrosis detected earlier can be treated with dilatation and stenting, though in failed cases, open surgical reparation is needed. Routine postoperative cystography to detect VUR is not recommended unless the patient has sustaining postoperative hydronephrosis in association with recurrent UTIs. Though, postoperative routine ultrasonographic follow-up is important [31].

In summary, several factors can be counted as the cause of complications; however the main principles can be listed as the following: (1) correct indication of the surgery, (2) preoperative sterile urine, (3) to have and to use the appropriate-sized instruments, (4) gentle manipulations during the surgery, (5) to be experienced so as to make the alternative maneuvers in challenging cases, and (6) routine postoperative follow-up.

Flexible Ureterorenoscopy

With the help of technological advances, the quality and durability of the instruments improved in association with miniaturization of the ureteroscopes. A significant amount of experience is being collected in retrograde intrarenal surgery for treatment of pediatric stone disease. Considerably high success rates are reported as in the adult counterparts [16–18]. Technique is similar as in adults. Use of guidewires and working under direct vision with fluoroscopic guidance are mandatory. In the surgical instrument set, the sine qua non elements are the flexible ureteroscope and Ho: YAG laser fiber (200 μm). Having a tipless nitinol basket and ureteral access sheath will facilitate the surgery. Although no study is present in pediatric series, an adult study on RIRS revealed that pre-stenting (versus no pre-stenting) reduced the risk of developing a ureteral access sheath-related severe injury by sevenfold [32].

Technique

Surgery starts with the cystoscopic placement of a guidewire up to the kidney. Although literature review gives controversial messages on the use of ureteral

access sheath, our experience revealed that the use of sheath will ease the entry to the ureter, traumatize the ureter less, and lengthen the life of the instrument. After accessing to the kidney, guidewire is removed, and the collecting system is endoscopically explored to locate the stone. During this exploration, fluoroscopic assistance with a contrast agent may be helpful. The stones in the pelvis and upper or middle pole calyces are easier to fragment. However, when the lower pole calyx makes a narrow angle with the pelvis, it can be challenging to reach the stone. The laser fiber within the ureteroscope may not permit to make required flexion to fragment the stone in place. In this case, stone can be retrieved with tipless nitinol basket and placed in a more suitable calyx or renal pelvis to be fragmented. The attempts to extract the fragmented stone particles are unnecessary and should be left for spontaneous passage. Postoperative stenting is controversial and depends on the course of the surgery and the surgeon's preference. In patients that entry to the ureter is not possible, placing a double J stent for a period of 2–4 weeks in order to have passive dilation might be an option.

Stone-free rates depend on the size and the location of the stone and reported to be between 90 and 100 % for stones smaller than 10–15 mm [33]. Particularly for the lower pole stones smaller than 15 mm, RIRS may be a considerable option. However, some series report that additional procedures are required more in patients with stones larger than 6 mm [18].

Complications are rare because of the use of small caliber instruments and selective use of active dilatation and mostly related to the lower ureteral orifice as perforation (<5 %), stricture (<1 %) [33].

Conclusion

Ureteroscopy seems as a first-line treatment option for ureteral stones in children. Use of appropriate-sized instruments is recommended. Routine postoperative follow-up is necessary to assess the long-term complications such as stricture or reflux.

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Chapter 30
Minimally Invasive Techniques to Approach Complications of Enterocystoplasty and Continent Catheterizable Channels

W. Robert DeFoor Jr. and Pramod P. Reddy

Abstract Continent lower urinary tract reconstruction is an invaluable tool to treat urinary incontinence, allow accessible intermittent catheterization, and protect the upper urinary tracts from high bladder pressures in children with neuropathic bladders. It has been used extensively in the past few decades around the world, and a large body of evidence has been accumulated as to its surgical outcomes and complications. The majority of these complications are manageable with a combination of medical and minimally invasive surgical interventions. This chapter will outline minimally invasive and injection techniques in the approach to complications such as stomal stenosis, acute inability to catheterize a channel, urinary incontinence, and bladder stones.

Keywords Continent urinary reconstruction • Mitrofanoff appendicovesicostomy • Malone appendicocecostomy • Stomal stenosis • Urinary incontinence • Bladder stones • Urinary retention

Introduction

Children with neuropathic voiding dysfunction who continue to have urinary incontinence and/or hostile bladder dynamics despite maximal medical therapy with clean intermittent catheterization and anticholinergic medication are considered for continent lower urinary tract reconstruction. The goal is to achieve a large capacity, low-pressure urinary reservoir that empties completely, is free of infection, and does not lead to renal deterioration. This can entail lengthening and tightening of the bladder neck to prevent urinary leakage from the native urethra as well as creation of a continent catheterizable channel to the abdominal wall to allow for accessible and efficient drainage. On occasion, the bladder will have to be enlarged with an

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Table 30.1 Stomal stenosis rates for continent catheterizable channels

Series	Year	Patients	Stomal stenosis (%)
Mitrofanoff AV			
Sumfest	1993	47	19
Cain	1999	100	12
Harris	2000	50	10
Thomas	2006	67	13
Welk	2008	67	6
Malone AC			
Curry	1999	300	30
Thomas	2006	50	14
Bani-Hani	2008	256	14
Rangel	2011	163	18

AV appendicovesicostomy, *AC* appendicocecostomy

enteric segment due to poor compliance and/or elevated detrusor filling pressures not responsive to medical management. In addition, many children with underlying conditions such as myelomeningocele, anorectal malformations, and tethered cord will have debilitating fecal incontinence and constipation. At the time of the major urologic reconstruction, an appendicocecostomy (antegrade continence enema, Malone ACE) can be performed to allow for more effective bowel management [1, 2]. Complications of these complex reconstructive procedures are not uncommon, however. They can range from minor difficulties such as stomal stenosis to serious life-threatening complications such as bladder perforation [3–6]. In addition, due to the mucus production from bowel tissue used in enterocystoplasty, bladder stones may form in the reservoir and lead to decreased capacity and recurrent urinary tract infections [7, 8]. This chapter will review the more common complications after these procedures and focus on minimally invasive and injection techniques to address these issues.

Stomal Stenosis

Since Mitrofanoff first described his procedure to facilitate clean intermittent catheterization via an abdominal wall stoma in 1980, the continent appendicovesicostomy has been used worldwide by reconstructive surgeons with great success [4, 5, 9–12]. Multiple series have documented its utility and the principle has been expanded to include detubularized and reconfigured intestinal segments (i.e., Yang-Monti, Casale modification), defunctionalized ureters, and even the fallopian tube [13–16]. Stomal stenosis at the cutaneous aspect of the channel is one of the more common complications of these channels (including those used for performing antegrade continence enemas). Contemporary series report a prevalence of up to 10–20 % (see Table 30.1) [4, 5, 17–19].

Most surgeons attempt to prevent stomal stenosis at the time of the creation of the channel by employing a U or V-shaped cutaneous flap to the spatulated end of

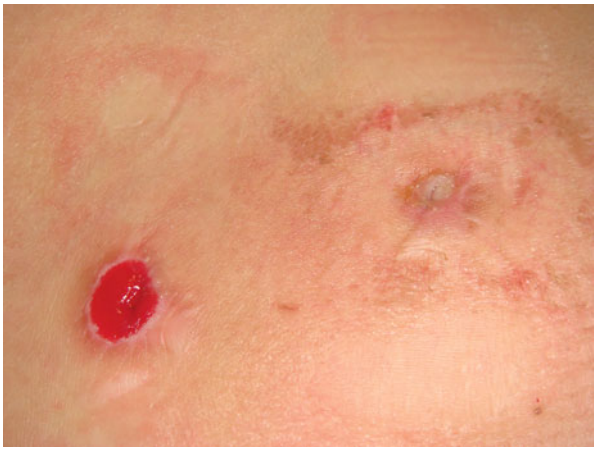

Fig. 30.1 Continent catheterizable channels in the right lower quadrant with a healthy Mitrofanoff appendicovesicostomy (*left*) and a stenotic Malone appendicocecostomy (*right*)

the appendix. Despite these efforts as well as the continual ongoing passage of a catheter through the channel on a daily basis to gently dilate the stoma and theoretically minimize stenosis, scarring and tightness of the orifice can occur. The likely culprit is poor vascularity of the distal tip of the appendix resulting in ischemia and scarring. Sometimes hypertrophic scarring (e.g., keloids) can result in difficulty passing the catheter.

When stomal stenosis occurs the patients may report some difficulty or pain passing the catheter into the main part of the channel in mild cases but be unable to engage the catheter into the stoma at all in severe situations. This can also lead to forced attempts to place the catheter resulting in a false passage of the channel and rupture of the appendix and even loss of the conduit. In our experience, the stomal stenosis rate seems to be higher in the appendicocecostomy channel used to perform the antegrade continence enema when both channels are created concomitantly using a split appendix technique. This could be due to the fact that the ACE stoma is only accessed once a day to once every other day, as opposed to the Mitrofanoff neourethra that is accessed multiple times a day). Figure 30.1 shows two separated stomas created with this technique with the well-vascularized Mitrofanoff channel compared to the stenotic appendicocecostomy channel.

Initial Intervention

When patients or caregivers begin to report difficulty with catheterization at the skin level, physical examination of the stoma may reveal a contraction of the orifice or sometimes a whitish circumferential scar with no visible mucosa. Simple initial interventions include placing a warm washcloth over the stoma for a few moments to soften the orifice prior to catheterizing the stoma and avoid further trauma to the tissues. Topical steroid cream such as 1 % triamcinolone may be applied 2–3 times

daily (or with each catheterization) for a period of 4 weeks (or longer if needed) to soften the cicatrix [20]. We will often give a caregiver a slightly smaller catheter to keep at home in case the usual size catheter will not pass easily. For appendicocecostomies (ACE) that are not generally cannulated but once a day or every other day for bowel irrigations, the single-use catheter used for clean intermittent catheterization can subsequently be used to gently dilate the ACE stoma 4–5 times a day after emptying the bladder.

In severe cases the stomal stenosis can be managed with intradermal injection of Kenalog 40 (1 mL = 40 mg of triamcinolone) with concomitant dilation with urethral sounds. If using this technique, it is helpful to leave an indwelling catheter in place for 72 h after the injection to allow for any inflammation to subside.

Endoscopic Management

In cases where simple topical interventions are not sufficient, inspection of the channel with a pediatric cystoscope with concomitant dilation of the channel can be employed. This can be helpful in umbilical stomas where surgical revision may be somewhat technically challenging. A guidewire can be passed into the bladder under direct cystoscopic guidance (and even manipulated out the native urethra if no bladder neck reconstruction has been performed). The cystoscope is removed and sequential dilators (Amplatz Renal Dilator Set, Cook Medical) can be passed over the wire, safely dilating the orifice. Attention should be maintained to avoid passing the rigid dilator across the continence mechanism to avoid causing iatrogenic urinary incontinence. Mid-channel strictures are less common but could be a result of an old false passage or traumatic catheterization. These can be managed in a similar fashion with careful maintenance of guidewire access. In both situations, leaving a silicone Council tip catheter (placed over the guidewire) for 1–2 weeks may facilitate healing and avoid recurrence. We have found daily gentamicin bladder irrigations to be helpful in avoiding infection with temporary catheter drainage of reconstructed bladders and catheterizable channels.

Surgical Revision

There is a relative high rate of recurrent stomal stenosis and at times, formal surgical revision becomes necessary when conservative measures have failed. A variety of techniques exist to revise a stoma at the skin surface, but in general, raising a U-shaped flap of uninvolved skin and re-spatulating the appendix through the cicatrix down to healthier tissue for anastomosis to the flap is successful. In more severe cases, the appendix can be circumferentially mobilized even down to the fascia and then the diseased portion excised. Generous double U-shaped flaps can be employed to reach the appendix for anastomosis.

Treatment Failure

In rare cases where dilation and then surgical revision have failed to prevent recurrence of stomal stenosis and major surgical revision or replacement of the channel is not ideal or desired by the patient, an indwelling tube can be employed to at least maintain the access. This would not be ideal for bladder channels but we have used them for ACE stomas in difficult cases [21]. Options include a MIC-KEY gastrostomy button (Kimberly Clark Worldwide, Inc.) or a Chait Trapdoor cecostomy catheter (Cook Medical). Both can be easily accessed to perform bowel irrigations. The former is held in with a balloon and is somewhat more protuberant from the abdominal wall. The latter features a small, soft access port that lies flat against the skin. A hinged cap opens for access to the internal part of the tube. The caregiver has to grasp and pull the tube slightly upward to open the trapdoor and engage the connector for the tubing from the enema bag. The tube is held in place by internal coils of the catheter. Both the gastrostomy button and Chait tube can be worn under clothing without any large, noticeable bulges. The gastrostomy button generally can be placed in the office setting after using a measuring device to assess the length of the channel. We have found that the Chait tube should be initially placed and subsequently exchanged in the operating room setting due to the stiffness of the coils and the need for a superstiff guidewire or rigid metal straightener. The need for exchanging the tubes is variable but in our practice is performed generally every 6–12 months or when they become heavily soiled. Complications of these chronic tubes are generally related to inadvertent displacement or granulation tissue around the catheter. The former can be managed temporarily by the caregiver at home by promptly placing and then taping in a standard catheter until a tube can be replaced electively by the provider. Granulation tissue may be treated with cauterization if symptomatic or causing troublesome bleeding.

Another alternative to stomal stenosis is to place an ACE stopper (Medicina Medical). This device is a 100 % silicone short plug with a circular 15 mm disc to keep the stopper in place and help maintain patency of the channel. They come in a variety of lengths and diameters to accommodate different size stomas (Fig. 30.2). It doesn't pass completely through the continence mechanism so it doesn't lead to leakage of fecal contents or erosion of the flap mechanism. The use of the stopper has been shown to decrease the rate of stomal stenosis when used prophylactically after creation of the channel [22].

Urinary Incontinence

One of the more frustrating complications of an appendicovesicostomy is urinary leakage from the stoma. This is typically reported as rare in most series ranging from 5 to 10 % [16]. However, this can be problematic for patients as the leakage is

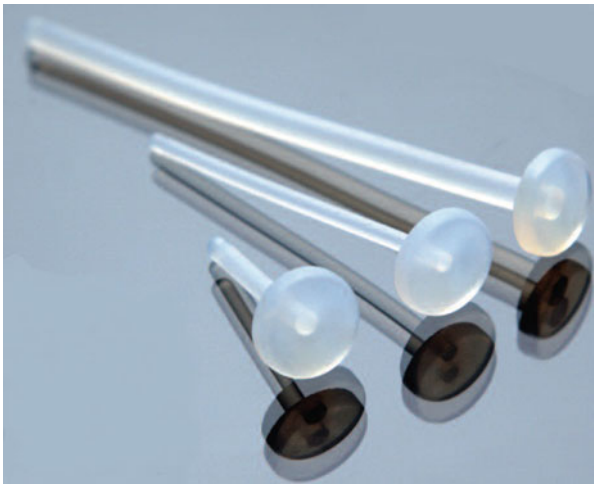

Fig. 30.2 Several available sizes of the ACE stopper (Printed with permission from Medicina Medical)

more noticeable and difficult to contain as compared to urethral leakage that may be managed with a diaper or pad. The etiology for the leakage may be technical with an inadequate or too short of a flap valve continence mechanism. Other possibilities may include underlying detrusor decompensation with disruption of the continence mechanism from elevated filling pressures. The initial evaluation should include a fluoroscopic voiding cystourethrogram as well as urodynamic testing to assess bladder anatomy, functional capacity, and bladder compliance.

Medical Management

Although an insufficient sphincter mechanism can be the culprit in channel leakage, the initial intervention, however, should be focused on maximizing the medical management. In addition, an index of suspicion for bladder deterioration or spinal cord tethering should be maintained. In a relatively small number of patients treated with an outlet procedure and a catheterizable channel without bladder augmentation, hostile bladder dynamics may result. A recent review of our experience showed that a very low outlet resistance preoperatively (in other words, a bladder never exposed to high or even normal storage pressures) and a postoperative tethered cord were independent risk factors for bladder deterioration [23]. Aggressive intervention with more frequent catheterizations, maximally tolerated doses of anticholinergics (including combinations of oral medications, intravesical preparations, and/or topical patches), and control of urinary tract infections with gentamicin irrigations are all reasonable to employ.

Botulinum A toxin injected into the detrusor muscle has been described as a treatment option in the management of high filling pressures, although the long-term durability is unknown, and thus the treatment may have to be repeated

periodically. The procedure can be performed using a pediatric cystoscope and a long dextranomer-hyaluronic acid injection needle. The dosage is typically 10 IU per kg up to a maximum dose of 200 IU. In our practice, methylene blue is mixed into the solution to allow for tracking of previous injection sites.

Endoscopic Intervention

If there are no new neurological symptoms and a filling cystometrogram shows a compliant, low-pressure reservoir with a low outlet resistance, then treatments based on augmenting or revising the continence mechanism are appropriate. Initial endoscopic approaches with injection therapy can be quite helpful in these situations. With the introduction of the sterile biodegradable gel, dextranomer-hyaluronic acid, in the United States in 2001, for the injectable treatment of vesicoureteral reflux, many reconstructive surgeons have employed it "off label" for the treatment of stress urinary incontinence or fecal leakage in catheterizable channels. The procedure can be scheduled as an outpatient in the operating room under general anesthesia. It can be performed by using a 9 Fr off-set or 10 Fr all-in-one pediatric cystoscope and a long injection needle. The continence mechanism is visualized in an antegrade fashion, and the dextranomer-hyaluronic acid injection is performed circumferentially to better coapt the mucosa. Catheterization is performed after the injection prior to emergence from general anesthesia to ensure it still proceeds smoothly. The bladder can be filled and if there is leakage with gentle suprapubic pressure, more of the gel can be injected. A temporary indwelling catheter is typically not necessary. Complications are rare but can include transient difficulty catheterizing the channel as well as persistent incontinence. Bladder neck incontinence can be treated in a similar fashion through the channel combined with a retrograde approach through the native urethra. Our short-term results with injection techniques for channel incontinence have been encouraging [24]. We have also performed a suprapubic cystotomy for the sole purpose of injecting a patient's bladder neck.

Surgical Intervention

If optimization of the anticholinergic and catheterization regimen has been performed, and endoscopic injection with a bulking agent is not successful, major surgical revision may be required. This can be approached through the original laparotomy incision. It is often helpful when revising a Mitrofanoff or ACE channel to dismember the stoma from the skin to gain more mobility. Careful attention needs to be maintained to the preservation of the vascularized pedicle. We have found that a long extravesical detrussorraphy (akin to an extravesical ureteral reimplantation) gives excellent continence outcomes along with assurance of a smooth, straight

course for catheterization. It is helpful to have the bladder full when choosing the site of implantation along the sidewall of the bladder.

When the channel is completely incompetent and has to be reimplanted again, the detrusor muscle is incised with the bladder full along the expected location of the submucosal tunnel. The tunnel to appendiceal diameter ratio is typically 5:1 or more. Detrusor flaps are created in the plane between the muscle and the underlying mucosa. A small mucosotomy is created distally for the sutured appendicovesical anastomosis with 4-0 or 5-0 polyglactin sutures. The serosa at the distal end of the appendix is anchored to the detrusor flaps in a "vest" fashion and hitched into place to prevent the tunnel from becoming foreshortened during the healing process. The detrusor flaps are then closed with simple interrupted 3-0 polyglactin sutures ensuring that the neohiatus is not constrictive. Each suture incorporates a small bite of the serosa of the appendix to keep it from sliding in the detrusor tunnel. The continence of the channel and its catheterizability can be checked with each suture placed in the detrusor flaps. It is helpful to hitch the sidewall of the bladder to the overlying abdominal wall to keep the channel from being angulated when the bladder is partially full or empty. Our practice has been to leave the channel intubated for 4 weeks if appendix is used but 6 weeks if reconfigured ileum (Monti-Mitrofanoff) was necessary. An endoscopic inspection under anesthesia is performed and then an overnight stay is arranged for catheterization teaching with our team of urology nurse practitioners.

With the increasing usage of laparoscopic techniques in urinary reconstruction, it is feasible to consider approaching a revision of either a Mitrofanoff of ACE channel with a minimally invasive technique. Single-center series of primary channel creation laparoscopically with or without robotic assistance have been described with safe and effective results [25–28]. While a replication of a leaking appendicocecostomy (ACE) may not require extensive dissection, a re-operative reimplantation of a failed Mitrofanoff appendicovesicostomy may be more technically challenging, particularly with obtaining laparoscopic access and dealing with intestinal adhesions after a major laparotomy. No series of channel revisions have been described in the literature as of yet; however, with the advance of technology, these techniques will most certainly be adapted to the reconstruction surgeon's armamentarium.

Acute Inability to Catheterize

A difficult situation in the care of these patients arises when there is acute difficulty passing the catheter into the channel. It is typically not a dire emergency to address an appendicocecostomy (ACE) that is acutely difficult to catheterize. In contrast, a Mitrofanoff channel that cannot be accessed puts the patient at risk of life-threatening sequelae if the bladder were to perforate, particularly when there is no leakage from the bladder neck, and the patient has a history of a bladder augmentation.

Risk factors for difficulty with catheterization also include a history of nonadherence with the prescribed regimen. In our series of bladder perforations, most patients had documented noncompliance issues as well as a history of bladder stones, possibly suggesting poor drainage habits [3]. Our office has a long-standing habit of checking with our home health care companies to ensure that the appropriate numbers of catheters are being ordered on a monthly basis. While this does not ensure that the catheter is actually being used as ordered, it does raise a red flag when the patient claims that they are dutifully performing the procedure but no refills have been ordered for several months. In addition, obesity is becoming a major public health concern in pediatrics and as patients with myelomeningocele age into adolescence and young adulthood, this can lead to difficulty with passing catheters into their channels and can complicate any surgical attempts to revise a continent reconstruction. Finally, female patients who become pregnant can be assured of increasing difficulty with catheterizations as the uterus enlarges progressively through the pregnancy and puts pressure on the bladder and channel [29, 30].

The acute management includes advising the patient to promptly present to be evaluated. If the patient is in distress and lives a considerable distance from the treating physician, the patient can be referred to the closest community hospital to have a suprapubic aspiration performed or even a percutaneous suprapubic cystostomy placed under ultrasound guidance. If the urologist cannot catheterize the channel in the office or emergency department, the patient must be taken to the operating room for endoscopic evaluation and management. One gentle pass of the catheter under anesthesia is appropriate but if unsuccessful, then inspection of the channel with a small (7 or 10 Fr) pediatric cystoscope is necessary

When treating a false passage, the cystoscope should be advanced into the channel and then withdrawn very slowly from the extent of the false passage back to the cutaneous stoma. The channel can be gently probed with a guidewire to find the true lumen. It can sometimes be difficult due to bleeding and poor visualization if multiple bedside attempts have already been made to drain the bladder. Often the true lumen is just under the surface of the stoma and may appear to be a slit-like opening of mucosa. Once guidewire access is obtained across the true lumen, the scope can be gently advanced over the wire to confirm that the wire is truly in the lumen of the bladder or cecum. The channel can be gently dilated and a Council tip catheter left indwelling for 2–4 weeks. A second-look endoscopy under anesthesia can be helpful to ensure that the lumen has healed and is catheterizable. In the unique case of an appendicocecostomy false passage, an antegrade contrast study either on the operating room table or in the radiology suite can rule out contrast extravasation from an unrecognized intestinal injury [31].

If the reason for the difficulty with catheterization was secondary to stomal stenosis, then steps can be taken as described previously in this chapter. Other possible causes include angulation of the channel when the bladder is extremely full. In some patients with nocturnal polyuria from gastrostomy tube feeds or renal insufficiency, an overnight catheter taped in to the stoma can be helpful to prevent difficulties in the morning when the bladder is full. We have also anecdotally noticed that children that are primarily gastrostomy tube fed can absorb a good deal of their

ACE irrigation leading to excessive urine output after their bowel cleanout and thus their catheterization regimen may need to be adjusted in light of the higher volumes.

Bladder Stones

Another common complication of enterocystoplasty is the formation of reservoir stones. In some series, the prevalence has been reported as high as 50 % depending on the predominant intestinal segment used for augmentation [7, 8]. The predominant stone composition is magnesium ammonium phosphate ("triple phosphate" or "struvite"). Struvite stones are potentiated by bacterial infections that hydrolyze urea to ammonium and raise urine pH to neutral or alkaline values. Urea-splitting organisms include *Proteus*, *Pseudomonas*, *Klebsiella*, *Staphylococcus*, and *Mycoplasma*. The possible causes for the calculi include mucus production, recurrent urinary tract infections (UTI) with urea-splitting bacteria, as well as nondependent bladder drainage through an abdominal wall stoma rather than the native urethra. The mucus may facilitate the growth of bladder calculi directly by heterogeneous nucleation or indirectly by allowing bacterial growth.

Typical clinical presentations include recurrent UTIs and urinary incontinence but typically not suprapubic pain or renal colic. They can also be incidental findings on routine follow-up ultrasound or radiographic imaging. New bladder instability on a filling cystometrography study in the absence of an active infection may also raise the suspicion for bladder stones. Recurrence rates are high thus an index of suspicion should be maintained in the long-term follow-up of these patients.

Medical Management

Other than uric acid stones which are rare in reconstructed bladders, none of the usual stone types are amenable to medical dissolution. Patients with high mucus loads in the urine or a previous history of bladder stones may benefit from prophylactic high-volume saline irrigations once or twice daily. Irrigation with 4 % urea solutions can be helpful in difficult situations. Recurrent urinary tract infections are initially treated with a switch from "clean" to "sterile" technique including single-use catheters. This may have to be authorized from third-party payers in the United States. Oral antibiotic suppression can be helpful as well as education of other caregivers not to treat asymptomatic bacteriuria unless it is one of the aforementioned urea-splitting organisms. A reassessment of the bowel management protocol is important to rule out chronic fecal retention and overgrowth of bowel flora. Finally, daily gentamicin bladder irrigations have been shown to safely instill the medication directly to the needed area without concern for absorption, even in patients with

bladder augmentation and renal allografts [32]. This can minimize the bacterial load when combined with an irrigation regimen to decrease mucus in the reservoir.

Surgical Intervention

Once a bladder stone has been diagnosed, it is reasonable to schedule an elective procedure for stone ablation and removal. For large stone burdens a simple cystotomy through a small suprapubic incision is a rapid and efficient method for complete stone extraction. A short overnight stay with an indwelling catheter will typically suffice for convalescence. For most stone burdens, however, an initial endoscopic treatment is appropriate. Controversy exists whether access through the appendicovesicostomy to treat the stones is safe, but in our experience, short treatments with a 10 Fr panendoscope through the existing channel have not resulted in iatrogenic incontinence or stomal injury. It is important not to attempt to basket out large fragments, however, as they may cause injury to the mucosal lining. Typically, a Holmium laser fiber is employed through a small pediatric cystoscope to break the stone into very small fragments. Suction tubing attached to one of the ports can be used to aspirate the residual fragments. Constant attention to the distension of the bladder is important to maintain during the treatment but temporary drainage after the procedure is usually not necessary.

For larger stone burdens being treated endoscopically, a suprapubic access is quite helpful [33]. A spinal needle can be placed under direct cystoscopic guidance through the previous suprapubic tube scar (or with ultrasound if there is concern about the proximity of intestinal tissue). A guidewire is passed through the spinal needle and the tract can be dilated up sequentially to accommodate an Amplatz sheath (Cook Medical). Another option is to use a smaller "peel-away" vascular access sheath that can be passed over the guidewire. The sheaths are made by several manufacturers and come in various sizes just large enough to accommodate the typical pediatric cystoscopes. The sheath can be used to pass a larger scope that can be allowed by a catheterizable channel and thus result in more efficient stone extraction. It is advisable to place a catheter in the appendicovesicostomy to vent the bladder during the procedure and avoid overdistension of an augmented bladder.

Conversely, a small cystoscope can be placed in the Mitrofanoff channel and then attach suction tubing to the percutaneous sheath. An assistant can then manipulate the sheath along the base of the bladder under direct cystoscopic vision to aspirate all the fragments. Stone extraction rates can be very high with these techniques with minimal morbidity and minimal residual fragments, which is important to decrease recurrent stones. A balloon catheter can then be placed through the sheath and the sheath removed. Our practice has been to leave the suprapubic tract intubated temporarily for at least 72 h with subsequent removal in the office.

Conclusions

Continent lower urinary tract reconstruction is an invaluable tool to treat urinary incontinence, allow accessible intermittent catheterization, and protect the upper urinary tracts from high bladder pressures in children with neuropathic bladders. It has been used extensively in the past few decades around the world and a large body of evidence has been accumulated as to its surgical outcomes and complications. The majority of these complications are manageable with a combination of medical and minimally invasive surgical interventions as outlined in this chapter.

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Chapter 31
Minimally Invasive Uro-Oncology

Nicholas G. Cost and Paul H. Noh

Abstract Despite advances in minimally invasive surgery and the increasing adoption of such techniques in pediatric urology, there remains a paucity of data or evidence-based recommendations for its use for pediatric or adolescent urologic oncology. However, there are a number of malignancies managed by urologic surgeons which have surgical indications that may be reasonably approached by minimally invasive surgery. There exist published reports of various adrenal (neuroblastoma), renal (Wilms tumor and renal cell carcinoma), testicular (germ cell tumor), and paratesticular (rhabdomyosarcoma) malignancies in children which have been managed with laparoscopy or robotic-assisted laparoscopy. Also, childhood prostate and bladder tumors, such as rhabdomyosarcoma, are routinely approached initially by endoscopy. The history of endoscopy and laparoscopy in pediatric urologic oncology provides a foundation for its current indications. In this chapter we will review the surgical techniques (including patient positioning, port placement, and selection of surgical instrumentation) and suggestions for approaching pediatric and adolescent urologic malignancies with minimally invasive surgery.

Additionally, we will review potential complications and critically discuss the controversy surrounding its use.

Keywords Pediatric • Adolescent • Cancer • Oncology • Malignancy • Urologic • Surgical • Minimally invasive • Laparoscopy • Endoscopy

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Abbreviations

COG	Children's Oncology Group
IDRFs	Image-Defined Risk Factors
IMT	Inflammatory Myofibroblastic Tumors
IPEG	International Pediatric Endosurgery Group
IV	Intravenous
IVC	Inferior Vena Cava
LN	Lymph Node
MIS	Minimally Invasive Surgery
NSS	Nephron-Sparing Surgery
PT-RMS	Paratesticular Rhabdomyosarcoma
RCC	Renal Cell Carcinoma
RMS	Rhabdomyosarcoma
RN	Radical Nephrectomy
RPLND	Retroperitoneal Lymph Node Dissection
SIOP	International Society of Pediatric Oncology
T-GCT	Testicular Germ Cell Tumors
TUR	Transurethral Resection
WT	Wilms Tumor

Introduction

The first report of "minimally invasive surgery" (MIS) in children was from Stephen Gans in 1971, when he successfully verified a contralateral inguinal hernia via an endoscope introduced through the known hernia sac [1]. For an oncologic indication, in 1976, Rodgers and Talbert first described thoracoscopy for diagnosing intrathoracic lesions in children [2]. More recently, Holcomb et al. described the laparoscopic experience of the Children's Cancer Group in 1995 [3]. In this report MIS was used mostly as a diagnostic tool with a limited role for therapeutic resection. However, the utilization of MIS for abdominal and urologic malignancy in children has slowly increased to the current era where it has been reported for radical [4–6] and partial nephrectomy [7–9] in renal tumors, adrenalectomy for adrenal tumors [10], retroperitoneal lymph node dissection (RPLND) for testicular, paratesticular, and renal malignancies [11, 12], biopsy of suspicious abdominal and retroperitoneal masses [3], and transurethral resection (TUR) of bladder and prostate masses [13]. This progress has been met with enthusiasm by many, but as with any new technology, controversy exists. Overall, the experience with MIS for urologic oncology has been more rapidly adopted in adults where many retrospective studies have demonstrated its safety and efficacy in a variety of indications [14]. In an attempt to assess the current state of

evidence for MIS in pediatric oncology, a Cochrane Review was recently published which served to highlight the extremely slow pace of adoption in children and adolescents as compared to adults. The authors of the Cochrane Review decry the complete lack of evidence-based recommendations for its use [15]. Their plea is for leaders in the field to systematically study the issue to provide future guidelines. Fortunately, the framework for such study is firmly in place with the impressive investigative power of the large pediatric oncology study groups, such as the International Society of Pediatric Oncology (SIOP) and the Children's Oncology Group (COG). With that goal in mind, we will review the history of MIS in pediatric urologic oncology, describe the current indications for its use, review and recommend surgical approaches, and critically discuss the controversy surrounding its use.

Throughout this chapter, we will continually emphasize that the goal of MIS is to recapitulate the open approach. This tenant of surgical practice is especially apt in the setting of oncologic surgery, in which cancer control is paramount and no "shortcuts" should be made that could compromise oncologic outcomes. To that end, we recommend that all such cases be approached with special attention and only undertaken by surgeons comfortable with both oncologic surgical principles and advanced laparoscopic techniques.

History and Background on Minimally Invasive Approaches to Pediatric and Adolescent Uro-Oncology

Adrenal Tumors

Currently, the most abundant literature on the use of MIS in pediatric oncology is in the setting of adrenalectomy [10]. Its relative popularity has led to guidelines by the International Pediatric Endosurgery Group (IPEG) for the minimally invasive management of adrenal tumors in children [16]. While there is no level-one evidence to support its use, a summary of the currently published literature indicates that MIS adrenalectomy, from both transperitoneal and retroperitonoscopic approaches, is safe in appropriately selected children [10]. Neuroblastoma comprises the vast majority of adrenal tumors in this population, and a consensus is that MIS is mainly indicated in those with encapsulated, low-risk tumors (younger patients with prenatal or mass-screening diagnosis) and those lacking image-defined risk factors (IDRFs). Additionally, the IPEG report mentions that MIS may be indicated in metastatic disease where the role of local control remains debatable [10, 16]. Other oncologic applications reported for MIS in pediatric adrenal tumors include adrenocortical carcinoma and pheochromocytoma [17, 18]. While a full discussion of the workup and management of the various pediatric adrenal lesions is outside the scope of this review, a broad

recommendation would be that MIS for pediatric adrenal tumors is most appropriate in smaller (less than 5 cm), discrete lesions not involving adjacent organs or vascular structures [16].

Renal Tumors

The most extensive experience with MIS for pediatric renal tumors comes from South America where laparoscopic radical nephrectomy (RN) has been routinely employed in a selected population of children with Wilms tumor (WT) after preoperative chemotherapy [4]. The advantages of post-chemotherapy surgery for MIS RN include a reduction in tumor volume and the resulting pseudo-capsule which decreases the risk of tumor rupture [6, 19]. There has even been an isolated description of laparoscopic RN for WT in the pre-chemotherapy setting [5]. However, the authors of that report comment on the concern of tumor rupture given the lack of a chemotherapy-induced pseudo-capsule. As for nephron-sparing surgery (NSS), there have been reports of minimally invasive partial nephrectomy for both WT and renal cell carcinoma (RCC) [7–9]. An important point highlighted in the case reports discussing minimally invasive NSS for WT is the advantage of post-chemotherapy surgery. The risk of tumor rupture is inevitably increased by the additional manipulation necessary for NSS as compared to RN, and thus, the post-chemotherapy pseudo-capsule is valuable in that respect, as is the reduced tumor volume. Unfortunately, a cautionary tale exists on this exact point in a case report of pre-chemotherapy laparoscopic NSS which was associated with prompt disease recurrence and diffuse peritoneal metastases. This inevitably raises questions about the possibility of missed intraoperative rupture [20]. Of concern in this case were the large tumor size relative to the child (10 cm) and the lack of lymph node (LN) sampling. This prompts our last point of emphasis: MIS for pediatric and adolescent renal tumors must replicate the open surgical approach which universally calls for a thorough LN sampling. This has been previously demonstrated as feasible and safe in a minimally invasive fashion in pediatric renal tumors [8].

Testicular and Paratesticular Tumors

The use of MIS for RPLND in boys with paratesticular rhabdomyosarcoma (PT-RMS) is possibly the most accepted use of MIS in pediatric urologic oncology. COG protocols mandate that all boys over 10 years of age with PT-RMS undergo ipsilateral staging RPLND [21]. Their protocols even go so far as to explicitly state that in experienced hands these cases may be approached with laparoscopy or robotic-assisted laparoscopy, both of which have been reported in an adolescent population [11, 12]. While the terminology describes this as a staging procedure,

since all PT-RMS cases receive postsurgical chemotherapy, the surgery follows the same templates used for testicular germ cell tumors (T-GCT) [22]. This highlights one of the controversial points surrounding the use of minimally invasive RPLND for T-GCT since it should strive to duplicate the open approach, and in the setting of primary and post-chemotherapy RPLND, it should be a therapeutic (not a staging) procedure. Regardless, there are reports of safe and effective minimally invasive RPLND in children and adolescents with T-GCT, both in the primary and post-chemotherapy settings [12, 23]. The long-term oncologic outcomes with this approach remain to be determined. However, just as minimally invasive RPLND should seek to replicate open RPLND intraoperatively, so should the postoperative care be similar. That is, after minimally invasive primary RPLND, patients should be managed as they would be after open primary RPLND including observation for node negative (N0) and low-volume nodal disease (N1) as recommended by the National Comprehensive Cancer Network [22].

Transurethral Management of Bladder and Prostate Tumors

Endoscopy is the preferred method for visual confirmation and tissue diagnosis in most cases of pediatric bladder and prostate tumors [24]. Most commonly these will be RMS but there are many reports of atypical pediatric bladder or prostate tumors, and the ability to utilize endoscopy, in the form of cystourethroscopy, to make a tissue diagnosis in a minimally invasive manner is a great advantage [25, 26]. Historically, these cases underwent upfront radical surgical resection. But as multimodality therapy has improved, there is increasing interest in minimizing the morbidity from radical excision. Currently, many advocate for initial endoscopic diagnosis followed by chemotherapy and potential radiotherapy [24]. This may lead to an increasing role for endoscopy in the form of a more aggressive TUR for residual masses after chemotherapy and radiation [13].

Suspicious Abdominal Lesions of Uncertain Origin

The use of MIS to diagnose suspicious abdominal masses is among the original indications as it was initially described by Holcomb et al. [3]. They utilized laparoscopy to assess newly discovered masses from the adrenal, liver, and ovary. Within the confines of pediatric urology, laparoscopy may be useful to arrive at a tissue diagnosis when other measures, such as image-guided percutaneous needle biopsy, have failed. This will most commonly be in the setting of neuroblastoma, but other examples described in the literature include less common diagnoses such as juxtarenal WT, retroperitoneal inflammatory myofibroblastic tumors (IMT), lymphomas, neurofibromas, and teratomas [3, 27, 28].

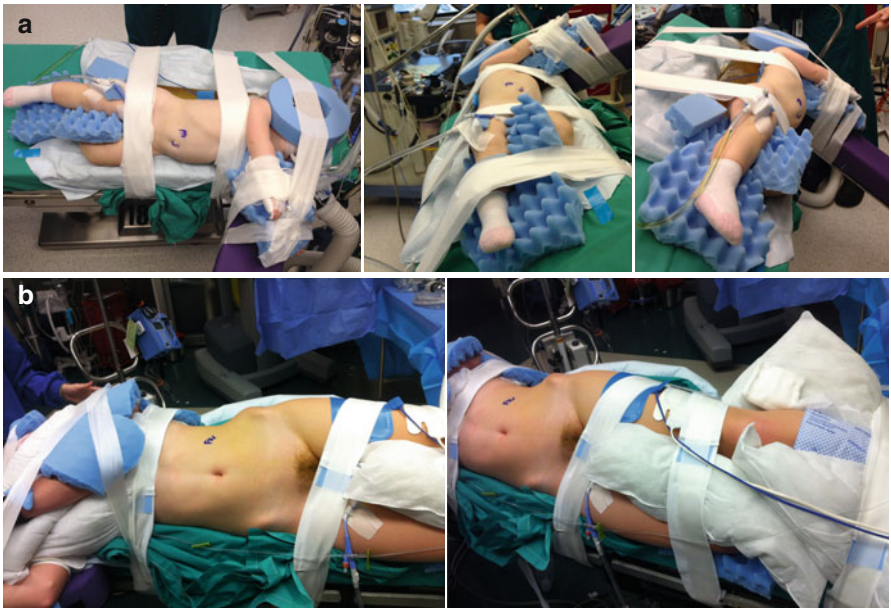

Fig. 31.1 Modified flank positioning for laparoscopic procedures. (**a**) – Pediatric: In this picture, the child is positioned for right-sided surgery; note the padding and securing of the legs in a "figure 4" position with the bottom leg flexed and the top leg straight. Also, we test the bed by rotating it to the two extreme positions. (**b**) – Adolescent: In this picture the adolescent is positioned for left-sided surgery; note the padding and securing of the legs in a "figure 4" position with the bottom leg flexed and the top leg straight

Indications and Techniques of Minimally Invasive Approaches

General Principles

In this section we will outline our general pre-, intra-, and postoperative recommendations including patient positioning, gaining peritoneal access, and management of the port sites. We typically use a mechanical bowel preparation. This is done at home and consists of a full day of clear liquids preoperatively and a combination of stool softeners, laxatives, suppositories, and enemas, depending on the age of the patient. This assists in decompressing the bowel to allow for the most intra-abdominal working space. For patient positioning, we recommend a modified flank position with the ipsilateral side rotated superiorly. A "figure 4" position of the legs as is standard for laparoscopic renal surgery is employed with appropriate padding [29]. We recommend securing the patient to the bed, with appropriate padding in three places: at the knee, the hip, and the chest. Additionally, the arm can either be brought across the body or positioned at the side based on surgeon preference. At this point, prior to prepping and draping, the bed should be fully rotated to demonstrate that the patient is sufficiently secured (Fig. 31.1).

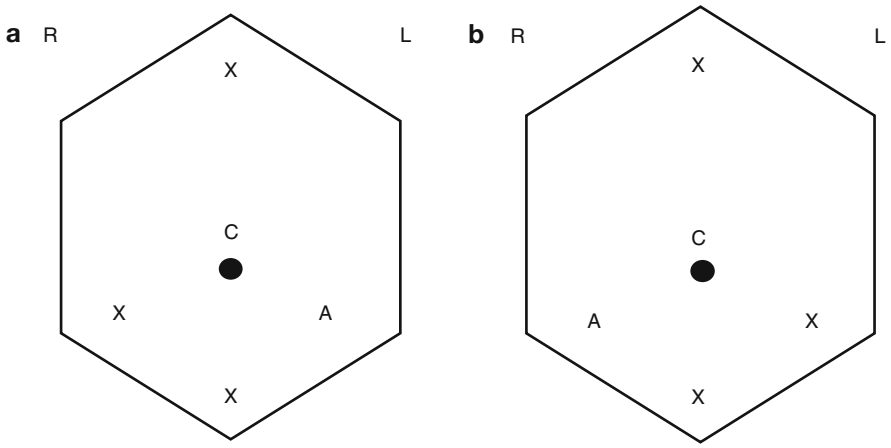

Fig. 31.2 Port placement for radical and partial nephrectomy. (**a**) – Right nephrectomy. (**b**) – Left nephrectomy. *R* Right, *L* left, *C* camera port, *X* working port, and *A* assistant port. Robotic working ports are 8 mm, standard laparoscopic working ports are 12 mm, and assistant ports are 12 mm. Of note, a robotic working port can be placed through a 12 mm standard laparoscopic port in case a standard laparoscopic instrument (i.e., vascular stapler) needs to be used via these ports

Peritoneal access is obtained with a Veress or Hasson technique depending on surgeon preference; however, we caution against excessive force or manipulation during port insertion as to prevent tumor rupture, specifically in large renal tumors. For radical or partial nephrectomy, regardless of standard laparoscopic or robotic-assisted laparoscopic surgery, we prefer a periumbilical camera port and three working ports placed subxiphoid, in the midline infraumbilically, and in the ipsilateral lower quadrant (Fig. 31.2). When planning for adrenalectomy, we utilize a periumbilical camera port with working ports placed subxiphoid and in the ipsilateral midclavicular line at the level of the umbilicus. Additional ports may be placed infraumbilically for the 3rd robotic arm or in the contralateral upper quadrant for an assistant port (Fig. 31.3). Last, for RPLND, we use a periumbilical camera port and three working ports placed subxiphoid, in the midline infraumbilically, and in the ipsilateral midclavicular line. Additional assistant ports may be inserted in the contralateral midclavicular line to allow for retraction and suction (Fig. 31.4).

Again, due to concern for tumor rupture, we encourage that all ports be placed under direct vision. All ports should be capable of accommodating a laparoscopic vascular stapler or should be convertible to accommodate a stapler to control the hilar vascular structures. In the setting of a robotic approach, we utilize all three of the working ports for robotic instruments, and so an additional assistant port can be placed to permit suction, retraction, etc. On a note about the port-site management, in many cases non-dilating trocars are utilized, and specifically the robotic working ports are non-dilating trocars. While there is literature to support either closing or not closing the fascia on laparoscopic port sites, it is our opinion that when using the relatively large-sized non-dilating robotic trocars and other trocars used to accommodate laparoscopic vascular staplers, closing the fascia of these incisions is beneficial to reduce the risk of port-site incisional hernia.

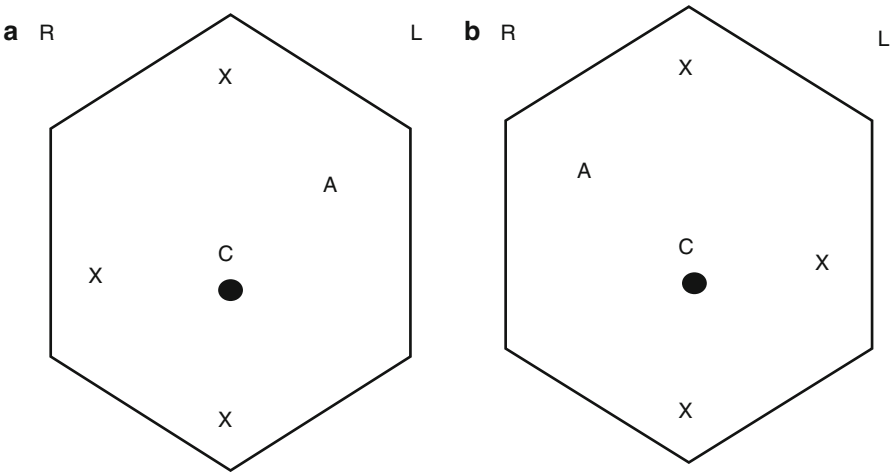

Fig. 31.3 Port placement for adrenalectomy. (**a**) – Right adrenalectomy. (**b**) – Left adrenalectomy. *R* Right, *L* left, *C* camera port, *X* working port, and *A* assistant port. Robotic working ports are 8 mm, standard laparoscopic working ports are 12 mm, and assistant ports are 12 mm. Of note, a robotic working port can be placed through a 12 mm standard laparoscopic port in case a standard laparoscopic instrument (i.e., vascular stapler) needs to be used via these ports

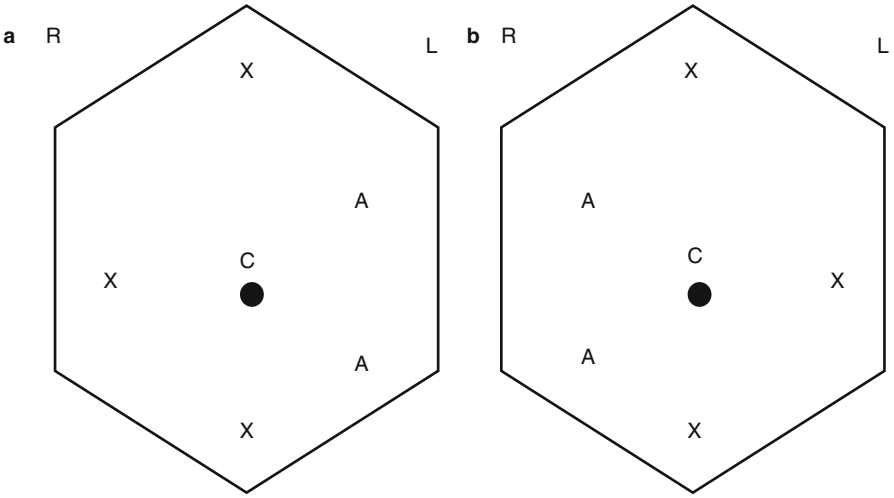

Fig. 31.4 Port placement for RPLND. (**a**) – Right RPLND. (**b**) – Left RPLND. *R* Right, *L* left, *C* camera port, *X* working port, and *A* assistant port. Robotic working ports are 8 mm, standard laparoscopic working ports are 12 mm, and assistant ports are 12 mm. Of note, a robotic working port can be placed through a 12 mm standard laparoscopic port in case a standard laparoscopic instrument (i.e., vascular stapler) needs to be used via these ports

Standard postoperative care consists of intravenous (IV) fluid resuscitation, adequate pain control, resumption of a progressive diet on postoperative day 0, and 24 h of antibiotic coverage. As a note on the diet after RPLND, we commonly

recommend a "no fat" diet for the 2 weeks after surgery to reduce the risk of a postoperative chyle leak. Our dieticians work with the patient and family on the appropriate education for this diet. The urinary bladder catheter is typically removed postoperative day 1 and activity encouraged. If a closed-suction surgical drain is left after partial nephrectomy, it can be pulled after the bladder catheter is removed, spontaneous voiding is resumed, and no increased drain output is observed. In cases of concern, the drain fluid may be sent for a creatinine level and compared to the serum level. Most reports describe a 2- to 3-day postoperative hospital stay after these laparoscopic or robotic-assisted laparoscopic surgeries.

Nephrectomy

The potential indications for minimally invasive radical nephrectomy (RN) in pediatric or adolescent patients include the most common primary renal tumors: WT, RCC, mesoblastic nephroma, and multilocular cystic nephroma. Additionally, there are reports of its use for both tumors of uncertain malignant potential, such as IMTs, and rare entities such as non-osseous Ewing's sarcoma [30, 31]. As we lack level-one evidence to recommend minimally invasive renal surgery in this population, the risks and benefits must be discussed in this context and carefully described to the patient and family. Additionally, it is important that regardless of the indication, a full multidisciplinary discussion be undertaken preoperatively.

In keeping with the limited available data, we would recommend the following general guidelines for minimally invasive RN: (1) When WT is highly suspected based on age, medical history, or genetic factors, we recommend presurgical chemotherapy be strongly considered. (2) As with all MIS, in an attempt to replicate the open surgery, we recommend a transperitoneal approach which includes full exploration of the peritoneal cavity and a thorough regional LN sampling. (3) While the port-site incisions allow for a potentially improved cosmetic result, a generous Pfannenstiel incision is recommended for intact kidney/tumor extraction to prevent tumor rupture during manipulation. (4) Similarly, an appropriately sized endocatch bag should be used to prevent tumor spillage. (5) Given that tumor size is associated with tumor spill [32] and that tumor size can be reasonably appreciated on preoperative imaging, we would suggest that only smaller, low-stage tumors, with no signs of locally advanced disease (i.e., no LN enlargement or venous tumor thrombus) be approached in this manner. Specifically, after a review of the most extensive experience with minimally invasive RN in this population, Duarte et al. recommend this approach be reserved for masses with the largest tumor diameter of <10 % of the patient's height [4]. (6) Last, the oncologic demands of the case take the highest priority and conversion to open surgery should be considered if any concerns arise.

We next proceed with a full exploratory laparoscopy to look for any signs of tumor dissemination. On right-sided cases we recommend liver retraction. Care must be taken if an external, fixed instrument is used as inadvertent movement can lead to liver injury. Alternatively, we have used a technique of passing a vessel loop or flexible guidewire through two percutaneously placed 14 gauge angiocatheters.

The vessel loop or wire is positioned underneath the liver and secured outside the body on some tension with hemostats to provide liver retraction. Commonly, aggressive dissection of the lateral hepatic attachments is beneficial to reveal the upper retroperitoneum, especially for upper pole tumors. The colon is then mobilized medially and the retroperitoneum is exposed after taking down the root of the mesentery and "kocherizing" the duodenum to reveal the inferior vena cava (IVC). At this point the ureter should be identified over the psoas muscle at the level of the great vessel bifurcation. Using one instrument to gently support the ureter superiorly (taking care to avoid injury to the gonadal vessels), the dissection proceeds cranially working along the IVC until the gonadal vein insertion, which we recommend preserving if possible. Continuing in this manner, the renal vein is then encountered.

On the left side we recommend aggressive dissection of the lateral splenic attachments as with appropriate medial mobilization of the colon, the spleen will fall with gravity and provide excellent exposure of the left upper retroperitoneum. Similar to the right side, the dissection starts by identifying the ureter. On the left, the dissection proceeds along the lateral side of the aorta until the left renal vein is seen crossing the aorta. Additionally, the left gonadal vein can be traced to its insertion into the left renal vein.

Next, the dissection should proceed by "sweeping the knee" and elevating the kidney and ureter within Gerota's fascia superiorly off of the psoas fascia. The robotic assistance of the 3rd arm or an assistant retracting or supporting the kidney and ureter is helpful to allow for two instruments to work at this objective. This visualization with superior elevation of the kidney will allow for identification of the renal vein anterior and the artery posterior. If identified at this point, it is typically a single artery, yet to branch; however, it is worth being always mindful for aberrant renal vessels. Prior to taking the vessels, we recommend completely dissecting them out to allow full visualization. This may require removing some lymphatic tissue surrounding the renal vessels. This should be kept for the final LN specimen. Once these vessels are prepared, we recommend taking the renal artery first, followed by the vein, both with a vascular stapler. Prior to taking the vein, the potential for tumor thrombus should be considered. If there is any concern, laparoscopic ultrasound can be of great assistance. Also, prior to firing the stapler the distal tip must be fully visualized as to not inadvertently entrap other structures. A laparoscopic suction device and laparoscopic sponge-tip instruments should be open on the field so that in case of stapler misfiring, vascular control can be achieved. After the hilar vascular structures are taken, the dissection continues cranially and may or may not include removal of the adrenal gland. After completing the superior dissection, taking great care to remain outside of Gerota's fascia, the lateral attachments are taken. Next, the ureter should be dissected down to at least the level of the iliac vessels, and if there is concern about ureteral tumor extension, down to the bladder. The ureter can be taken with a clip or suture.

The specimen should immediately be placed in a laparoscopic endocatch bag which is then closed to prevent tumor spillage or soiling. Next, attention should be given to LN sampling. We recommend, at a minimum, removing all lymphatic

tissue from the ipsilateral great vessel from the level of the bifurcation to above the renal hilum. The technique is similar to that described for RPLND where one instrument serves to elevate the LN packet as it is "split" over the anterior surface of the great vessel. The packet is then retracted as another instrument(s) dissects this free of the vessel. The robotic assistance of the 3rd arm or an assistant retracting the LN packet is helpful to allow for two instruments to work at this objective. These LNs should be placed in an endocatch bag and sent to pathology fresh as a separate specimen.

To remove the specimens, we recommend grasping the endocatch bag string through the ipsilateral lower quadrant port under laparoscopic visualization. This port can then be removed and its incision generously extended laterally and medially to accommodate removal of the kidney/tumor in the endocatch bag. This fascia may be closed and pneumoperitoneum reestablished to allow for a final inspection of the resection bed. We recommend irrigation with warmed sterile water, taking care to ensure hemostasis under conditions of reduced pneumoperitoneum. The patient bed can be rotated to allow the colon to fall back laterally and a final look with the laparoscope ensures there is no malrotation of the small bowel mesentery.

Partial Nephrectomy

(Please refer to accompanying Video 31.1)

The potential indications for minimally invasive nephron-sparing surgery (NSS) in pediatric or adolescent patients would mirror indications for open NSS. That is, the approach to NSS should not supersede the oncologic considerations. Thus, the currently reported indications include WT (bilaterally, in a solitary kidney, or in a patient with a WT predisposition syndrome) and RCC [7–9]. As with minimally invasive RN, given the current lack of level-one evidence to recommend minimally invasive renal surgery in this population, the risks and benefits must be carefully described in this context to the patient and family. In addition to our previous recommendations on minimally invasive renal surgery, if NSS is considered for WT it should be done utilizing the applicable COG or SIOP protocols following presurgical chemotherapy. Additionally, approaching a renal mass with NSS does not change the necessity of LN sampling. Lastly, we would recommend that minimally invasive NSS be reserved for ideally located masses (exophytic, noncentrally located) and for surgeons experienced with minimally invasive NSS.

The surgery begins with full exploratory laparoscopy followed by exposure of the retroperitoneum and great vessels with appropriate hepatic or splenic retraction as mentioned in the section on RN. The deviation from the RN approach is to start with the LN sampling prior to mobilizing the kidney. This is done by removing all of the lymphatic tissue from the ipsilateral great vessel from the level of the bifurcation to above the renal hilum. The technique is similar to that described for RPLND where one instrument serves to elevate the LN packet as it is "split" over the anterior surface of the great vessel. The packet is then retracted as another instrument(s)

dissects this free of the vessel. The robotic assistance of the 3rd arm or an assistant retracting the LN packet is helpful to allow for two instruments to work at this objective. These LNs should be placed in an endocatch bag and sent to pathology fresh as a separate specimen. Complete LN dissection at this stage of the procedure is beneficial as it allows for clear visualization of all renal hilar structures and facilitates the vascular control for NSS.

We next completely mobilize the kidney as with RN. Then, using laparoscopic ultrasound guidance we delineate the location and extent of the mass. Gerota's fascia is opened over the mass, and with a generous margin we dissect down to the renal parenchyma and slowly dissect the perirenal capsular tissue away from the normal kidney to expose the mass. Again, using laparoscopic ultrasound guidance, we note the extent of the mass and cauterize this outline on the capsule. We then turn our attention to renal vascular control and start by identifying the artery and vein and placing vessel loops around them with a clip and a short tail for rapid identification. Clamping the vessels for NSS is a matter of surgeon preference and experience. We prefer to clamp the renal artery with laparoscopically applied internal vascular clamps via the assistant port.

The fat overlying the mass is left in place to be sent with the specimen. Next, working with two instruments and suction from a bedside assistant, the mass is resected using cold scissors and direct visualization to reduce the potential for inadvertent tumor transection. A tip for this is to use two insufflators to allow for aggressive suctioning without losing pneumoperitoneum. Also, an additional port or the robotic 3rd arm should be utilized if it can be of assistance to hold the kidney or mass during the resection. The resection and tumor positioning should be planned out prior to vascular clamping so that the operative time under ischemic conditions is minimized. We then close any opened collecting system as needed and obtain hemostatic control with directed "figure of 8" sutures for exposed, transected vessels, applying thrombin gel, a surgical cellulose bolster, and separate renorrhaphy sutures through the renal capsule using the "sliding-clip" technique [33]. The vascular clamps are then removed. Of note, we typically use a dose of IV mannitol immediately before and after vascular clamping. The mass and nodes are placed in an extraction bag and removed via the lower quadrant port with adequate extension as described for RN. Specimens must be sent for frozen pathologic analysis to determine the need for additional resection and to ensure a negative margin. The resection site should be reinspected after reducing pneumoperitoneum and hemostasis ensured. A closed-suction drain can be left per surgeon preference.

Adrenalectomy

Neuroblastoma is the most common childhood adrenal malignancy and thus is the most common oncologic indication for MIS adrenalectomy. However, during the workup of an adrenal mass, less common entities such as adrenocortical carcinoma or pheochromocytoma may be encountered and could be reasonably approached by

MIS. While initially, MIS was utilized as a diagnostic tool to biopsy pediatric adrenal tumors, there is increasing experience with therapeutic resection. For small, low-stage tumors with no evidence of invasion on preoperative imaging, minimally invasive resection may be considered if adhering to surgical oncologic principles. More specifically, size greater than 6 cm, enlarged veins, and involved adjacent organs or vessels are relative contraindications to MIS adrenalectomy for neuroblastoma [16].

As for the surgical approach, MIS adrenalectomy can be performed either transperitoneally or retroperitoneally, with multiple published reports describing both techniques. We prefer a transperitoneal approach as it serves to recapitulate the open surgery and the remaining report will focus on this technique. Additionally, given the varied venous drainage of the left and right adrenal, many surgeons consider left adrenalectomy to be less technically challenging. However, both left and right MIS adrenalectomy are feasible.

The surgery begins with exploratory laparoscopy. Subsequently, for right-sided cases, dissection of the lateral hepatic attachments and retraction of the liver is necessary. After identifying the hepatic flexure and upper pole of the kidney, the colon is reflected medially so as to expose the duodenum and the superior two-thirds of the kidney. The duodenum is "kocherized" medially to expose the IVC. We prefer to use a laparoscopic, expandable fanned retractor via an assistant port to rotate and retract medially on the IVC. At this point, dissection continues by creating a plane superior to the renal vein down to where the psoas muscle is visualized. Prior to starting this dissection, it is important to review the preoperative imaging and remain cognizant of the potential for upper pole renal vessels which should not be sacrificed. Next, using this plane to "sweep the knee" and elevate the upper pole of the kidney and the adrenal, small pillars of tissue are dissected along the lateral IVC and taken using a laparoscopic bipolar tissue-sealing device. This dissection is continued along the IVC as an assistant medially retracts and rotates the cava until the adrenal vein is encountered. This may be taken with a sealing device, hemostatic clips, or a vascular stapler per the surgeon's preference. Next, we incise Gerota's fascia along the upper pole of the kidney but leave posterior attachments intact to allow for inferior retraction of the kidney and subsequent movement of the adrenal. Additionally, the lateral attachments are kept to prevent it "falling down" into the working field. Once the adrenal is completely freed along the medial aspect, alongside the IVC, we use a bipolar sealing device to complete the superior and lateral dissection while inferiorly retracting the adrenal via its remaining renal attachments. The last step is taking the inferior, posterior renal attachments.

On the left side we recommend aggressive dissection of the lateral splenic attachments as with appropriate medial mobilization of the transverse colon, splenic flexure, and descending colon. In doing so, the spleen will fall with gravity medially and provide excellent exposure of the left upper retroperitoneum. This will also expose the renal hilar vessels and superior portion of the kidney. A fanned retractor from the assistant port can be used to retract the tail of the pancreas medially and further expose the renal vein as it crosses the aorta. As with the right-sided approach, prior to creating the plane identifying the left adrenal vein draining into the left

renal vein, you must consult the preoperative imaging and be cognizant of the potential for upper pole renal vessels. Next, we control the adrenal vein as it enters the renal vein with clips or a bipolar sealing device. Then the space above the renal vein is developed down to the psoas muscle, and similar to a right adrenalectomy, the upper poles of the kidney and adrenal are swept up and retracted. This allows dissection cephalad along the edge of the aorta until reaching the upper most extent of Gerota's fascia. Next, identify the upper pole of the kidney and incise Gerota's but leave the posterior most attachments to allow for inferior retraction. By retracting the kidney inferiorly, it then pulls the adrenal inferiorly as well and allows completion of the superior and lateral dissection with the bipolar tissue-sealing device. Last, the posterior attachments to the upper pole of the kidney are taken.

For tumor removal, we then entrap the adrenal in an endocatch bag and remove it by extending the inferior port incision. Once this is closed and pneumoperitoneum is reestablished, we remove any remaining lymphatic tissue overlying the ipsilateral great vessel where it was exposed for adrenalectomy. We recommend irrigation of the bed with warmed sterile water and taking care to ensure hemostasis with reduced pneumoperitoneum.

Retroperitoneal Lymph Node Dissection (RPLND)

(Please refer to accompanying Video 31.2)

The indications for minimally invasive RPLND in children and adolescents consist of (1) boys 10 years and older with PT- RMS who require an ipsilateral staging RPLND, (2) adolescents with stage I or IIa testicular non-seminomatous GCTs who elect for primary RPLND, and (3) patients with renal tumors where an ipsilateral RPLND is desired. These procedures have been demonstrated as safe and effective in children and adolescents but are not widely used due to the technical demands and concern about long-term oncologic outcomes [8, 11, 12]. However, the minimally invasive approach seeks to replicate open surgery by removing all lymphatic tissue in the same, well-defined surgical templates (Fig. 31.5), not only sampling suspicious nodes [22].

Regardless of whether the surgery is a right-, left-, or bilateral-template RPLND, we begin the case with the right-side up in flank to allow for full mobilization of the ascending colon, root of the mesentery, and duodenum. This provides the most visualization of the retroperitoneum and with aggressive dissection and retraction, even the left portion of the template can be reached in this manner. However, if the case is a left-template RPLND and the full dissection cannot be obtained from the right-sided view, after completing the precaval and inter-aortocaval portion, the patient may be repositioned and re-prepped on the left side to mobilize the splenic flexure and descending colon to allow for the para-aortic nodal dissection that may have been difficult from the prior position. The port placement is carefully considered for this possible transition, so that in repositioning to the other side, the same port sites will be utilized with the potential for an additional assistant port. While the

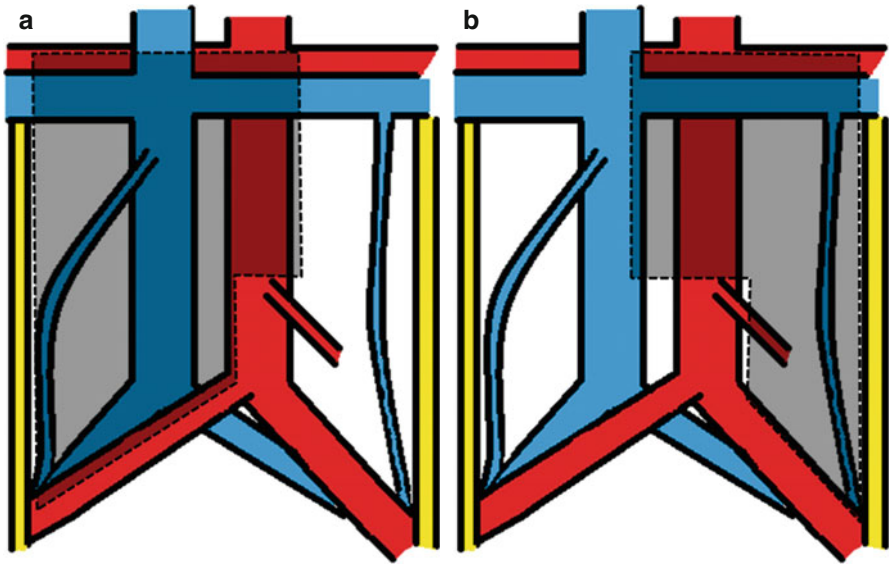

Fig. 31.5 Surgical dissection templates for RPLND. (**a**) – *Right*: Remnant right cord structures and right gonadal vein, para-caval LNs, precaval LNs, inter-aortocaval LNs, and preaortic LNs. (**b**) – *Left*: Remnant left cord structures and left gonadal vein, para-aortic LNs, preaortic LNs, and inter-aortocaval LNs

oncologic goals of the surgery are paramount, attention should also be paid to nerve sparing when at all possible. On the right side the postganglionic sympathetic fibers are identified behind the IVC. Their takeoff from the sympathetic chains is always near lumbar veins, so great care should be taken in controlling lumbar vessels. On the left side it is easiest to identify the postganglionic sympathetic nerves at the ganglia as they leave the sympathetic chain and then dissect them prospectively as they course anterior to the aorta before joining the hypogastric plexus. Also, we minimize our use of clips to control lymphatic channels and only clip as needed at the distal and proximal extent of the dissection and tend to more routinely employ the bipolar tissue-sealing devices.

Starting with a right-template RPLND, the ascending colon and hepatic flexure are mobilized medially. It is helpful to take down the lateral hepatic attachments and achieve medial and superior hepatic retraction which will allow full visualization of the right renal hilum. Care must be taken if an external, fixed instrument is used in this fashion as inadvertent movement can lead to liver injury. We commonly utilize an alternative method for hepatic retraction as described in the section on renal surgery.

We start by identifying the right gonadal vein and separating this from the ureter and dissecting it down to the spermatic cord remnant and up to the insertion in the IVC. One tip for preventing ureteral injury during dissection is to place a rubber band around the ureter and then use a silk suture on a straight needle passed percutaneously by the assistant to laterally and superiorly retract the ureter. Next, as the gonadal vein is dissected superiorly to the IVC, it is taken at that junction with clips

or a bipolar tissue-sealing device. Then it is dissected into the right internal inguinal ring where the remaining stump of the spermatic cord is identified and taken. This is placed in an endocatch bag as a separate specimen and removed.

We then turn our attention to the "split and roll" of lymphatic tissue over the IVC. In order to fully visualize this working space, we find that a fanned retractor placed via the assistant port helps with medial rotation of the bowel and ultimately medial rotation of the cava in order to visualize the lateral lumbar vessels. Using an assistant through one of the working ports, or a third arm with robotic assistance, we superiorly and laterally retract the LN packet to have two working instruments focusing on dissecting the packet off of the vessel. We work both cranially and caudally, slowly progressing from the renal hilum to where the ureter crosses the iliac vessels. When a lumbar is encountered it is fully dissected out and either clipped or taken with a bipolar tissue-sealing device. Our recommendation is to leave more length on the side of the lumbar vessel going to the great vessel as it will allow easier control if a clip is dislodged. Also, in case of a caval laceration during dissection, rather than panicked attempts to convert, we recommend direct pressure using a laparoscopic sponge (which should be kept in the peritoneum during the surgery for rapid use if necessary). Most venous bleeding can be controlled with pressure, and if necessary, directed suture repair.

Once the para-caval nodes are freed as far as possible, we work on the caval side of the inter-aortocaval nodes by having an assistant or one of the robotic arms retract the packet medially as we use two working instruments to dissect it off the cava. This will expose the medial lumbar vessels which are controlled as described above. Of note, when working in the inter-aortocaval space, we recommend prospectively identifying the right renal artery to avoid injury. After the lumbars are taken, the nodal tissue behind the cava can be directly visualized. The nodal packet from both the para-caval and caval portion of the inter-aortocaval nodes can be taken off of the anterior spinous ligament and passed into an endocatch bag.

If the visualization is still adequate with this position and using the assistant to retract the bowel, the lymphatics over the aorta are split. If necessary, the patient can be repositioned and redraped to achieve full aortic node dissection. One point prior to changing position is to ensure that all nodal tissue on the right has been taken and that hemostasis is achieved so that a return to this position is not required. If this is done with a robotic approach, it requires more organization since the robot itself requires repositioning, we recommend to completely switch the operative table orientation rather than move the robot to the other side of the room. This requires forethought by the surgical and anesthesia teams.

On the left side, the descending colon and splenic flexure are mobilized medially and the lateral splenic attachments are taken down to allow gravity to pull the spleen and tail of the pancreas medially and expose the upper left retroperitoneum and the left renal hilum. Again, a fanned retractor from an assistant port in the contralateral lower quadrant helps fully reveal the preaortic space. Care should be taken as the lymphatics are split over the aorta to note the takeoff of the inferior mesenteric artery which should be preserved in cases of primary RPLND. For a right template, this is as far as the aortic node dissection needs to be taken. For a left template, the

procedure mirrors that of the right where the gonadal vein should be identified and separated from the ureter and the ureter retracted gently laterally to avoid injury. The gonadal vein is dissected up to the renal vein junction where it is ligated and then dissected down to the remnant spermatic cord. For the pre- and para-aortic nodes, an assistant or the third robotic arm will laterally retract the LN packet as two arms work from the renal hilum to the iliac vessels. When lumbar vessels are encountered, they are controlled as mentioned above. Last, the inter-aortocaval space is visualized again, now from the left, and the aortic side of these nodes is taken by medially retracting the packet and working to slowly and carefully dissect it off the aorta. Once the medial lumbar vessels are controlled, direct visualization under the aorta is obtained and the lymphatic packets can be taken off of the anterior spinous ligament and placed in an endocatch bag.

We finish the case by reducing pneumoperitoneum and ensuring hemo- and lymphostasis. We then irrigate the surgical bed with warm, sterile water. We follow this with a regimen of fibrin sealant, thrombin gel, and surgical cellulose placed over the great vessels. The operative table is rotated back to a neutral position, and inspection with the laparoscope ensures that the colon falls into place in an appropriate position so that the small bowel mesentery is not twisted.

Transurethral Endoscopy for Resection/Biopsy

Most bladder or prostate tumors in this population will present with symptoms of abdominal or pelvic pain associated with dysuria or obstruction. This typically prompts imaging; however, the importance of cystourethroscopy to visually confirm the lesion and provide a minimally invasive tissue diagnosis cannot be understated. The indications for cystourethroscopy in this setting are any suspicion of a bladder or prostate mass on history, imaging, or examination. The endoscopy should determine, if possible, the location of the tumor since treatment decisions about local control will be based on its resectability and proximity to important anatomical structures as the bladder neck, trigone, and ureteral orifices. For this reason, a growing role for cystourethroscopy is following initial chemotherapy and/or radiotherapy to determine if a bladder-sparing resection can be undertaken. Recent reports suggest that chemoradiation may be sufficient therapy for selected cases of bladder and prostate RMS and that TUR at the completion of chemoradiotherapy can help determine the presence or absence of persistent malignant elements [13].

The patient and family should be consented for an exam under anesthesia, diagnostic cystourethroscopy, and complex catheter placement. Additionally, there is potential need for suprapubic tube placement, fluoroscopic imaging, TUR of the lesion, and percutaneous perineal or transrectal needle biopsy. The pathologist should be informed of the case ahead of time and the fresh samples taken directly to the pathology suite without tissue fixation so that a preliminary diagnosis can be made. Even more importantly, this ensures that adequate tissue is provided to make

a diagnosis. If needed, additional resection may be undertaken, or an alternative strategy, such as perineal or transrectal needle biopsy, utilized. As a last resort, an open incisional biopsy may be required. These options should be discussed with the family during the consent process to prepare them for all possible events.

Once adequate anesthesia is achieved, the child is placed in a lithotomy position. An electrocautery grounding pad is placed to prepare for TUR. The abdomen, genitals, perineum, and rectum should all be prepped in case of a need for any or all of the various surgical approaches. Also, as a note on the anesthesia, a paralytic is preferred for TUR to prevent an obturator nerve reflex which may lead to inadvertent bladder perforation. We begin with a full exam under anesthesia including a rectal examination to assess for bladder mobility or fixation. Next, we use an appropriately sized cystourethroscope to visualize the entire urethra and bladder neck. Upon entering the bladder, irrigation should be stopped and a urine sample collected for cytology. Next, the bladder should be fully assessed, specifically noting the presence of a lesion and its position relative to the bladder neck, trigone, and ureteral orifices. The potential for both a TUR for biopsy or future bladder-sparing resection should be evaluated.

For TUR, an appropriately sized resectoscope should be selected, and if necessary, the urethral meatus dilated. The resectoscope and working sheath should be advanced into the bladder under direct vision. Next, the camera with the working channel and a loop cautery are placed through the working sheath. It is important to either use a continuous flow resectoscope or be cognizant of the need to periodically empty the bladder to avoid over distention. Prior to resecting, the irrigation solution must be changed to either sterile water or sorbitol. We prefer sorbitol; however, the risk for "TUR syndrome" and hyponatremia still exists. For this reason, the resection should be as brief as possible using a limited amount of irrigation. Additionally, we recommend checking a pre- and postoperative serum sodium level. The current is set to 40 W for cutting and to 20 W for coagulation on the electrocautery, and a foot pedal is appropriately positioned. If the current must be increased to allow for resection, it can be slowly done under the surgeon's direction. Directed biopsies should be resected in a smooth motion from posterior to anterior, starting on the lesion's lateral edge. This is done with cutting current to prevent coagulation artifact from confounding the pathologic assessment. Separate specimens are resected individually and labeled to aid in the orientation and pathologic evaluation. A deeper biopsy into the muscle is recommended to assess for muscle invasion. In many cases, as in most bladder or prostate RMS, a full TUR is not possible or advised. Accordingly, the appropriate extent of resection should be completed at this time. It is imperative that the surgeon or surgeon's assistant takes the samples fresh to pathology so that they can determine the tissue adequacy for diagnosis. Additional tissue may be required for the biologic studies involved in RMS treatment protocols. The case should be concluded by achieving hemostasis with directed coagulation via the resectoscope. The irrigation inflow should be stopped and continued bleeding investigated. A urinary catheter is then placed and the bladder decompressed for 2–3 days at a minimum. If there is concern for bladder rupture, the catheter should be left longer and a cystogram done prior to removal. Be mindful

that many of these children suffer from bladder outlet obstruction at diagnosis and a mechanism of urinary drainage will be necessary until the tumor is resected, debulked, or reduced by chemotherapy and/or radiation.

Controversy of Minimally Invasive Surgery for Uro-Oncology

Just as we appreciate the potential benefits of MIS, we recognize that such approaches carry unique risks and potential complications. For the most part, controversies surrounding the broad adoption of MIS for pediatric urologic oncology are concerned with complications or deviations from standard surgical oncologic principles. Therefore, we reemphasize our admonition to prioritize the oncologic demands of these surgeries. First, delicate manipulation and dissection is necessary to reduce the risk of tumor rupture, most specifically in WT. Thus, we caution against MIS in the setting of pre-chemotherapy WT. As has been reported [5], it is feasible, but no robust data exist on its safety and thus it cannot be recommended as routine practice. Since neoadjuvant therapy is not a routine part of RCC management, MIS is generally more accepted for RCC than WT. Second, as is demanded by open surgery for pediatric and adolescent renal tumors, a thorough LN sampling is mandated. It is feasible via MIS and should be included in all cases. The lack of adequate node sampling risks under-staging and has been demonstrated to negatively affect outcomes [34, 35]. Therefore, as a plea to encourage minimally invasive surgeons to raise the bar higher in order to increase acceptance of these modalities, we must strive to meet and exceed all oncologic standards of care and LN sampling is one such instance. Third, to increase acceptance of these modalities, it is important to "set oneself up for success" with careful patient and case selection. Smaller, lower-stage tumors are obviously more appropriate for MIS, and injudicious case selection can lead to disastrous outcomes as evidenced by reports of diffuse peritoneal spill after MIS for a large WT [20]. In the setting of adrenal tumors and neuroblastoma, this means selecting smaller tumors without evidence of IDRFs, specifically those encroaching on vascular structures and adjacent organs. Last, a minimally invasive approach does not diminish the therapeutic intent. As an example, the use of minimally invasive RPLND in testicular cancer should be done with curative intent. As mentioned earlier, acceptance of these modalities will only come when they are held to higher standards of care than the equivalent open surgery.

Conclusions

MIS for pediatric and adolescent urologic oncology presents an exciting new frontier for a field of medicine already full of advances. This has made pediatric urologic oncology the example for the potential improvements in survival and outcomes

that may be achieved with rigorous study and evidence-based medicine as seen by the last 50 years of success in WT management. Early reports demonstrate a variety of potential indications for MIS in pediatric and adolescent adrenal, renal, testicular, and paratesticular malignancies. These preliminary descriptions must be built upon to well define the ultimate role of MIS in pediatric and adolescent urologic oncology. For this reason, we encourage the inclusion of these modalities into the current structure of the large cooperative study groups. We strongly advise pediatric surgeons and urologists to rigorously apply surgical oncologic principles in these cases to ensure that outcomes are maximized. In general, technical feasibility has already been demonstrated, as is reviewed within this chapter. Now we must prove safety and efficacy.

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Chapter 32
Preparing the Child for Minimally Invasive Surgery and What Parents and Children Truly Remember

Omaya I. Banihani and Michael C. Ost

Abstract Minimally invasive urological surgery in children is advancing and becoming the first choice in the management of elective urological procedures. Children are unique population that is different from adults in their anatomy, physiology, and response to the stress of surgery that also vary with the child's age and maturation. This must be remembered when planning surgical intervention in the pediatric population.

In this chapter we will discuss the process of patient selection, preparation, and patient/parents counseling before any minimally invasive pediatric urology surgery.

Keywords Minimally invasive • Consent • Preoperative evaluation

Growth and Maturation

After birth, important and rapid physiological changes take place in all the vital organs of the newborn that makes the pediatric patient unique, with different physiological response to the stress of anesthesia and surgery.

Growth

After birth the growth and development in children occurs at a rapid pace, especially in early childhood. A full-term newborn grows at a rate of 25–30 g/day

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over the first 6 months of life, leading to a doubling of the birth weight during this period. In the first 12 months of life, an infant's birth weight is typically tripled. By 3 years of age, birth weight is expected to quadruple, and by 10 years of age it will increase 20-fold from the birth weight. Body length increases by approximately 50 % in the first year of life and by threefold by 10 years of age [1]. Previously a 10 kg body weight was used as a cut point to perform laparoscopic/robotic surgery, but recently a successful robotic surgery was performed in 2.2 kg neonate to fix diaphragmatic hernia [2] and a series of laparoscopic robotic-assisted surgery was done in 45 patients less than 10 kg [3].

Cardiac Function

The neonatal and pediatric myocardium is stiffer and less compliant compared with the adult heart. This results in diminished preload capacity. In addition, infants and children have relatively higher resting heart rates. As a result, cardiac output in children is heart rate dependent, because the stroke volume is relatively fixed. Decreases in heart rate in infants and children will result in decreases in cardiac output to a greater extent than a similar decrease in heart rate in an adult patient. The pediatric heart is significantly less responsive to inotropic agents, because it has reduced intramyocardial calcium release [4, 5]. Patients with congenital heart disease will need careful evaluation by pediatric cardiologist and pediatric cardiac anesthesiologist before surgical urological procedure.

Respiratory Function

Lung development depends on intrauterine fluid dynamics, and processes such as oligohydramnios will result in pulmonary hypoplasia. In the postnatal period, lung development continues for 1 year after birth. This stage is characterized by maturation of the terminal saccules into alveoli. At birth, the lung contains approximately 20 million saccules, and at approximately 5 weeks postnatal, these begin to develop into the 300 million alveoli expected to be present by 8 years of age. The most robust development of the alveoli occurs before 4 years of age. After 8 years of age, lung volume increases because of increase in alveolar size, not from an increase in alveolar number [6, 7].

Renal Function

GFR and tubular function double by 1 month of age [8], and over the first 3 months of life, renovascular resistance continues to decrease, which results in further rises

in GFR. Following this relatively rapid rise, GFR continues to increase more slowly toward adult levels, which are reached by 12–24 months of life. The maturation of renal tubular function lags behind the maturation of glomerular function, and therefore the neonate can concentrate urine to only approximately 50 % of adult capability [9–11].

Immune Function

Neonates have increased susceptibility to bacterial infections, which is predominantly due to deficiencies in neonatal host defense mechanisms. Premature infants are at even higher risk. This susceptibility is due to several factors related to the immaturity of neonatal leukocytes, including neutrophils, monocytes, T and B lymphocytes, and NK cells, and also with deficiencies in the complement activation system. Although the neonatal period presents the highest risk of infection for children, the immune system is not fully competent until approximately 8 years of age [12, 13].

Preoperative Evaluation

The perioperative management of patients undergoing urologic surgery continues to evolve. It has become standard for patients undergoing even the most sophisticated and complex urologic procedures to be admitted on the same day of the surgery, and so the urologic surgeon is responsible that the patient has been fully evaluated by other physicians in the hospital and presents to the operating room in the most optimized medical condition, and this will result in improved patient safety and obviate the need for unnecessary cancelled surgeries due to the inadequacy of medical optimization.

Patient Selection

Urological surgical procedures are performed for a wide range of congenital and acquired pediatric urogenital disorders and this can be from day one of life. Important points in the patient's history to be considered when selecting patients for minimally invasive urological surgery:

1. Complete prenatal and neonatal history including any events during pregnancy and delivery should be discussed as these events may influence the child's current state of health. Infants with a history of prematurity and/or intrauterine growth retardation (IUGR) are at increased risk for surgical adverse events due to increased risk of pulmonary hypoplasia.

2. History of congenital heart disease, chronic lung disease, or other medical diseases that include, but not limited to, asthma, rheumatic heart disease, upper respiratory tract infection, diabetes mellitus, immune deficiency, hematological diseases, renal disease, neurological diseases, inborn errors of metabolism, cancer, chromosomal abnormality, and skin disease.
3. Current health status that include recent upper respiratory tract infection, urinary tract infection, recent hospitalization, diarrhea, and skin infection.
4. Nutritional history, acute or chronic gastrointestinal and liver disease.
5. Obesity.
6. History of allergies.
7. Current and past medications including use of steroids, anticoagulants, and chemotherapy.
8. Personal history of previous surgical intervention and previous anesthesia complications.
9. Family history of allergies, hematological diseases, and postoperative and anesthesia complications. Child of a Jehovah's Witness.
10. Social history like household smoking, adolescent smoking, use of drugs, and alcohol consumption.
11. Pregnancy and contraception in teenage girls.
12. Skeletal anomalies that include scoliosis, spina bifida, spinal injury, and any orthopedic surgery.

Contraindications for Minimally Invasive Urology Surgery

1. Absolute contraindications:
   - Poor cardiopulmonary reserve that will impair CO2 exchange
   - Active infection (UTI, intra-abdominal infection)
2. Relative contraindications:
   - Bowel adhesions due to previous abdominal surgery, peritoneal dialysis, or history of necrotizing enterocolitis (NEC)
   - Bleeding diathesis. Note: Laparoscopic and Robotic procedures are not contraindicated in children with ventriculoperitoneal (VP) shunts

Preoperative Preparation

Preoperative Information

Communication and information giving is vital in all aspects of heath care even more so for operative patients. Proven benefits of establishing a preoperative information program are increase in patient satisfaction, less demand for postoperative

analgesics, and decrease length in hospital stay [14]. Patients preferred mode of information about surgery includes direct contact with health care professional and printed literature (only 40 % of verbal info will be retained) [15]. Simplified language and simple drawings should be used to deliver information to the patient and his/her parents.

Informed Consent

Informed consent can reduce the risk of liability yet increase patient satisfaction. In the preoperative informed consent, be sure to include three additional comments that are to be initiated by the parent and witness: (1) that the parent/guardian understands the consent, (2) that all questions have been answered and there are none remaining, (3) and that all risks, benefits, and possibility of conversion to an open procedure and alternatives to the procedure are understood. When blood and/or other blood product transfusion is possible during surgery, written consent should be obtained. Jehovah's Witness refuse blood transfusions because of the belief that the "life force" resides in their blood. Most medical care providers agree that in an emergency it is unacceptable for a parent to make a conscious decision that could result in the loss of a minor child's life; in such cases, appropriate medical therapy, including transfusion of blood products, is administered against the wishes of the family [16]. It is therefore imperative that the surgical and anesthesia teams define a plan with the parents in the event that blood is required. Perioperative volume expanders, such as albumin and hemodilution, and blood banking are acceptable to some individuals, depending on their interpretation of biblical passages [17].

Preoperative Testing

When planning for a minimally invasive procedure such as straight laparoscopy or robotic-assisted laparoscopy, there are group of tests that should be done before subjecting the patient to pneumoperitoneum that includes prothrombin time (PT) and partial thromboplastin time (PTT), hemoglobin and hematocrit (H/H), and serum creatinine (SCr). Urine culture (UCx) should be done for high-risk patients or when opening the bladder is intended.

Preoperative Nothing by Mouth (NPO) Guidelines

Preoperative NPO instructions are crucial to avoid unnecessary respiratory complications during elective urological surgery and will prevent cancellations or delays. Simple instructions are given to the parents in the preoperative counseling and the day before surgery. For all the healthy children, 2-hour (h) fasting is required if

ingested clear liquids (like water, fruit juice without pulp, and clear tea), 4 HR fasting for breast milk, 6 HR for infant formula, 6 HR for nonhuman milk, and 6 HR for light meal (like toast and clear liquids). Fatty meals can delay gastric emptying. Both the amount and type of foods ingested must be considered when determining an appropriate fasting period [18].

Preoperative Fluid Management

Perioperative fluid therapy begins with an estimation of fluid deficit by the anesthesia team. The total requirement for maintenance fluids can be calculated using the Holliday-Segar formula as follows: for patients who weigh 0–10 kg the hourly replacement is 4 mL/kg/h (hr), patients who weigh 11–20 kg the hourly replacement is 40 mL/h + 2 mL/kg/h, and patients who weigh more than 20 kg the hourly replacement is 60 mL/h + 1 mL/kg/h [19].

Antimicrobial Prophylaxis

The Centers for Disease Control and Prevention (CDC) provided guidelines for surgical antimicrobial prophylaxis (SAP) [20], but these were broad and general and did not specifically address urologic surgery. The CDC surgical wound classification system of clean (class I), clean-contaminated (class II), contaminated (class III), and dirty/infected (class IV) can be applied to pediatric urologic procedures [21]. SAP is recommended for (1) all surgery in neonates less than 72 h of age because of possible exposure to maternal pathogens and, particularly, compromised immunologic capacity; (2) major class II surgery; and (3) all class III and IV surgical procedures [21]. Antibiotic use in class I and minor class II operations has not been studied and remains based on surgeon's preference. Recommendations for SAP are provided in Table 32.1 [22]. The timing of SAP administration is critically important, and the first dose should be given 30 min to 3 h prior to incision to achieve bactericidal levels of the antibiotic at the site of incision.

Preoperative Bowel Preparation

The use of mechanical bowel preparation is standard practice before urological procedures such as cystoplasty was based on observational data. This preparation was popularized beginning in 1966 and became routine practice by the early 1970s. Antibiotics were subsequently added to decrease the bacterial load [23]. The aim of mechanical bowel preparation with or without antibiotics is to decrease the intestinal content and the intraluminal bacterial content, which it has been

Table 32.1 Recommendations for SAP

Operation	Preoperative dose
Neonatal (<72 h old) surgery	50 mg/kg ampicillin and 2.5–3 mg/kg gentamicin
Class I	Cefazolin 25 mg/kg
	Vancomycin (if MRSA or MRSE likely) 10 mg/kg
Class II	Cefazolin 25 mg/kg
	Ampicillin 50 mg/kg
	Gentamicin 2.5–3 mg/kg
Class III	Cefoxitin 40 mg/kg
	Cefotetan 40 mg/kg
Class IV	Cefoxitin 40 mg/kg
	Cefotetan 40 mg/kg ± 2 mg/kg gentamicin
	Gentamicin 2 mg/kg + 10 mg/kg clindamycin

Source: Data from McInerny [22]
MRSA methicillin-resistant Staphylococcus aureus, *MRSE* methicillin-resistant Staphylococcus epidermidis

postulated will reduce complications. Recent studies in adult colorectal surgery have shown an increased risk of abdominal septic complications, including anastomotic leakage, with bowel preparation [24]. The incidence of postoperative complications did not differ between children with or without preoperative bowel preparation. Those who did not receive bowel preparation had a significantly shorter hospital stay and avoided the unpleasant procedures [23]. Known side effects of bowel preparation are due to dehydration and electrolyte disturbances such as hypokalemia and hyperphosphatemia. Caution in patients with renal and/or cardiac impairment. The use of preoperative bowel preparation usually is by surgeon's preference.

What Parents and Children Remember

The urologist should assume that parents and older children will remember everything good and bad. The statement that "Technical excellence will provide patient satisfaction" is false. Memories whether positive or negative will be imprinted from the time in the clinic or emergency room up until surgery and the postoperative period.

It is well known that significant preoperative anxiety is associated with a difficult and often prolonged anesthetic induction [25, 26]. If the child is not treated in an *age-appropriate manner*, the entire perioperative experience will likely be compromised. Conversely, if the psychological and emotional aspects of a child's condition distract caregivers from the primary medical and surgical concerns, a successful outcome may be compromised [27]. There is consensus among anesthesiologists regarding the need for the treatment of a child's anxiety before surgery [28] because for a lot of children, the immediate postoperative course reflects their experience during induction.

Table 32.2 Responses to anesthesia and surgery by age and some ways to ameliorate their anxiety

Age	Response	Solution
Infant	Fear of separation from parents and exhibit stranger anxiety	Parental involvement in the perioperative experience
Toddler	Fear of loss of control	Enable the child to make choices, such as asking if the child has a color preference for his or her hospital gown
Preschool	Fear injury and they tend to think in concrete terms and therefore may take statements literally	Caution when choosing the language used with this age group
School	Fears that he or she may not meet the expectations of adults	Clearly explained the expectations from them
Adolescent	Fear of death and not understanding their body function	Reassurance without prompting

Table 32.2 [27] shows how the age of the child will affect his/her responses to anesthesia and surgery and some ways to ameliorate their anxiety.

Summary

In the process of preparing a child for minimally invasive urological surgery, we should take in consideration their unique anatomy, physiology, and psychological needs. Collaboration with other physicians will help to optimize the condition of high-risk patients and minimize the chance of cancelling the surgery. Preoperative information and consent will help the parents and old children to understand the procedure and lower the postoperative anxiety and lower the chance of liability. Use of bowel preparation before surgery depends on the surgeon's preference. Perioperative anxiety is different with age.

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