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Update on the Minimally Invasive Approach in Paediatric Urology: Remote Help for Human Hands?

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Abstract

The innovations of minimally-invasive surgery have successfully been applied to pediatric surgery. Some special caveats apply to children, however. Confinements of space and the small intravsacular blood volume pose special risks in small infants. Unlike in adults, placement of the first troikar should always be under direct vision. There is no consensus whether minimally-invasive approaches should be used in children under one year of age.

Single-port approaches have also been used in children and for renal surgery both the transabdominal and the retroperitoneosocopic approach are feasible. Pneumovesicoscopy has successfully been used for ureteral reimplantation and robotic-assisted surgery for children has also been established. The cost-effectiveness of many techniques remains an unsolved problem.

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1. Brief history of laparoscopy

Endoscopic examination of the abdominal cavity was first performed in 1901 by Georg Kelling, who introduced the concept of celioscopy; however, this stepping stone in the history of surgery was marked by static periods mixed with significant advances. The use of a cystoscope for diagnostic purposes in the abdomen was reported later [1–3], and with the introduction of carbon dioxide (CO_2) insufflation in the late 1950s to enhance vision and space, gynaecologists improved on what had become known as *laparoscopy* [4–6]. The term *minimally invasive surgery* (MIS) was first used in 1987 by British urologist John Wickham commenting on the evolution of surgery from a ‘‘brutal and ablative’’ medieval epoch to the modern efforts to minimise the impact of surgery on the patient [7].

Increased costs of consumables and prolonged initial operative times compared with the open approach prevented widespread acceptance of laparoscopic therapeutic applications in adults until the 1990s [8,9]. Another major drawback with MIS at the outset was the inability to demonstrate a measurable difference in postoperative recovery time [10]. Many more years passed before advantages over open techniques could be demonstrated in terms of shorter recovery times, better functional results, and equivalent outcomes [11–13]. Robotic surgery, initially reported in the mid-1990s, must tread a similar path to demonstrate efficiency [14–16].

Although MIS was attempted in adults earlier than in children, its adaptation to children was first reported in 1976 with the use of laparoscopy as a diagnostic tool for cryptorchidism [17]. Its widespread use was probably delayed by the fear of pathophysiologic changes that insufflation might cause in children because of the relatively small size of the cavities [18].

The real debate that that still needs to be had is about the futility of MIS in infants aged <1 yr. Proponents argue that the approach allows visualisation and exposure with

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decreased wound tension and inflammatory reactions. Those not in favour take the point of view that incisions for open surgery are small and that the sum total of laparoscopic incisions equals the total length of the open incision [19].

2. Anaesthetic challenges in children

Insufflation increases abdominal pressure, moving the diaphragm cephalad and thereby decreasing compliance. Anaesthetists must address the major issues of increased abdominal pressure, Trendelenburg position, and CO_2 absorption because they might impair cardiovascular function and ventilation, induce cerebral vasodilation, and affect urine output [20–22]. Respiratory rate, peak airway pressures, and end-tidal CO_2 are significantly increased, whereas only minor changes are observed in heart rate and O_2 saturation. Intra-abdominal pressures up to 12 mm Hg seem to be well tolerated, and pressures <10 mm Hg do not induce any clinical haemodynamic effects [21,23].

3. Surgical challenges in children

Although claimed by some authors to be safe and effective in children [24], use of the Veress needle is associated with higher complication rates. Open placement of the first trocar under direct sight should be preferred in the paediatric population [25,26].

The relatively small size of the abdominal cavity in children is a major challenge for the surgeon because any gas leak immediately produces rapid desufflation, which makes working in an already small operative field even more hazardous.

Port placement is of paramount importance with MIS in children. Due to the relatively restricted space, trocars must be placed carefully under direct sight to avoid bleeding and to allow optimal use of the available space [27]. The limited workspace often hampers optimal use of the instruments and limits ergonomics. The ports cannot be inserted as deeply in a child as in an adult because doing so would further limit the already restricted operating field. When introducing instruments, care must be taken not to injure the adjacent organs, which are never far away in the limited paediatric space. Electrocautery must be used with care, although instruments are now built with isolated sheaths to avoid thermal injuries to adjacent organs [26].

Bleeding is a major concern in children, with small blood volumes making any uncontrolled bleeding rapidly problematic. The surgeon can avoid bleeding by using the transillumination technique during port placement to avoid the epigastric vessels. Moreover, blood is an effective light absorber, making any control of bleeding more difficult [28].

The theatre layout should be well known to the team to avoid making MIS even more difficult [29]. Building a team that will be familiar with MIS in children is of paramount importance and will improve the operative time, the patient outcome, and the comfort of the team itself [30].

In reviews on laparoscopy with >5000 procedures performed in children, morbidity was reported in approximately 5% of cases, varying among studies, with the majority of complications related to access [25,26,31]. Minor complications (Clavien 1 or 2) varied between 1% and 4%, whereas major complications (Clavien 3 and 4) were reported in 0.3–2.8% and often were attributed to the learning curve [25,26,31,32].

Because MIS in children has been proven safe and effective, a broad panel of procedures has been established, including relatively simple procedures (impalpable testes, varicocoele, peritoneal dialysis access, and nephrectomy for a nonfunctional kidney) and more difficult procedures such as partial nephrectomy in duplex systems, pyeloplasty, adrenal lesions, and bladder reconstructive surgery [33–38].

4. Approaches

The open retroperitoneal approach was traditionally the preferred route for paediatric urologic surgery, paving the way for retroperitoneoscopic adaptation [39]. The retroperitoneoscopic approach is used increasingly for nephrectomy and pyeloplasty, without any added morbidity, and it avoids the breach of the peritoneal cavity.

The learning curve is longer because the retroperitoneal space has no fixed landmarks except the quadratus lumborum and the psoas muscle [40]. In addition, the space is virtual and needs to be created by the surgeon. Retroperitoneoscopy offers the advantage of avoiding the abdominal cavity, making bowel injury unlikely, and has the advantage of containing potential postoperative urinary leakage. The retroperitoneal access for MIS in children is much easier because it seems easier to create a space behind the peritoneum than in adults. A custom-made dilating balloon is often used (those used in adults are too big) to create this space safely without breaching the peritoneum [41] (Fig. 1).

The transperitoneal approach can be used for upper and lower urinary tract surgery but was not the preferred route for open urologic surgery. The restricted space led the

Fig. 1 – The custom-made balloon used to create the retroperitoneal space: A three-way tap, a Simplastic catheter, and the finger of a glove are assembled.

surgeons developing laparoscopy to adopt the transperitoneal approach for most urologic procedures for which a retroperitoneal approach had been preferred in traditional open surgery. This approach offers the advantage of a wider operating field and easily recognisable anatomic landmarks [39]. It is also a natural space that does not need to be created artificially by blunt dissection [42].

Pneumovesicoscopy is an elegant approach that can be used for intravesical ureteral reimplantation and represents an advance in MIS within paediatric urology. With this approach, the bladder is insufflated with CO_2 through the suprapubic access. This allows a cross-trigonal procedure of reimplantation with good outcomes reported, although the procedure is challenging with limited working space in small bladders [43].

5. Stealth surgery

Stealth surgery refers to the emerging techniques that aim to complete complex procedures without leaving any visible evidence on the body surface, and it is performed with incisions in inconspicuous locations [44]. These techniques attempt to reduce or eliminate skin incisions in an effort to improve cosmesis and reduce convalescence [45]. Various acronyms have been devised to describe the different technical procedures, such as LESS (laparoendoscopic single-site surgery), SILS (single-incision laparoscopic surgery), and SPA (single-port access surgery). The terms refer to a single incision, usually placed at the umbilicus, through which multiple instruments are placed via a single device or closely spaced multiple ports. Due to the lack of proper intra-abdominal instrument triangulation, suturing appears to be extremely demanding, even for a skilled laparoscopist [46,47]. The variety of procedures is similar to that for any transabdominal laparoscopic approach. Suturing is considered the most challenging step of LESS pyeloplasty, with an increased risk of postoperative urinary fistula in adults and a subsequently increased risk of recurrence [46,48]. The main advantage is improved cosmesis and psychosocial aspects; any visible scar is avoided and concealed in the existing umbilicus. However, no significant benefit has been objectively demonstrated. The use of the da Vinci platform (Intuitive Surgical, Sunnyvale, CA, USA) in single-site procedures might eventually offer advances in MIS [47].

6. Robotic assisted surgery

The feasibility of the laparoscopic approach and its safety and efficacy have been demonstrated [25,31,33,49,50]; however, the steep learning curve of laparoscopy, the technical difficulties related to two-dimensional vision, the compromised dexterity due to the well-known *fulcrum effect*, and the transmission and amplification of the surgeon's hand tremor have contributed to make laparoscopy a technique that takes considerable time to master.

The robot-assisted technique has the potential to allow for wider adoption of MIS in paediatric urology. The learning curve has been shown to be shorter, with outcomes comparable to those of open procedures [35,51,52]. Many publications have reported that the introduction of robotics after a well-conducted training program is safe and effective [53,54]. In a recent prospective cohort study to determine the learning curve for paediatric urology fellows in paediatric robotic pyeloplasty, the authors concluded that the operative time for robotic pyeloplasty performed by fellows consistently decreased with cumulative surgical experience [54]. Another recent publication highlighted the value of a multitechnique robotic training curriculum including dry-lab in addition to virtual and clinical training in the use of the robotic platform [55].

The robotic platform seems to offer solutions to the main pitfalls of conventional laparoscopy. At present, the da Vinci Surgical System is the only robotic platform approved by the U.S. Food and Drug Administration [56]. The technology provides movement transfer and is a mechanical slave device that allows enhanced visual magnification and definition [47]. It provides 7 degrees of freedom compared with 5 in classical laparoscopy. It also eliminates hand tremor and facilitates variable scaling of the instrument motion. More precise, delicate movements in small areas are possible. In addition, the ergonomic position of the surgeon at the console reduces the stress of conventional laparoscopy and decreases fatigue. It also provides for steady robot-held camera viewing [47].

The current robot was developed for use in adults but can be used in children, although the instruments are large and are not fit for small children [35]. Even the 5-mm instruments, with the wider space they need to fully develop their EndoWrist (Intuitive Surgical) possibilities, are not ideal for children [56]. Consequently, trocar placement is of paramount importance. Although a distance of approximately 8 cm is recommended between trocars in adults to avoid arm collision, this is difficult in children. Reported outcomes are becoming available and seem equal to the current gold standards [33,50,57].

Robotic assisted surgery is a well-established approach in adult urology, with significant benefits reported in radical prostatectomy [12]. It is also increasingly being used in paediatric urology for nephrectomy and pyeloplasty as well as for more complex procedures like bladder reconstructive surgery, for which traditional laparoscopy is difficult. In paediatric urology, nephrectomy and pyeloplasty are standard procedures that can be performed by the robot without any change in outcomes compared with laparoscopic and open approaches [33,36,50]. Since 2005, there has been an increase in the total number of pyeloplasties performed using minimally invasive techniques. An estimated 750 robotic pyeloplasties were performed in the United States between 2008 and 2010 [58]. Although reconstructive bladder procedures are increasingly being done with the robot in children, we will have to wait for further studies proving the benefit of this approach [57].

7. Cost-effectiveness of robotics in paediatric urology

Current studies have not found the robotic approach to be cost-effective [59]. With increasing and widespread use, it is possible that robotic surgery might prove to be cost-effective at some point [60]. In the United States, with its unique healthcare system, robotic surgery is widely available; however, in other countries, the prohibitive costs are still a major drawback. Cheaper robotic systems are being developed in other parts of the world, and hopefully, at some point, this will drive the costs down. Cost-effectiveness is probably the only issue that still needs to be addressed to allow use of the robotic platform.

8. Conclusions

MIS in children has come a long way, overcoming challenges and proving its efficacy, although this has taken several years. Just as laparoscopy did 20 yr ago, robotic surgery has entered a stage at which outcomes and safety have been demonstrated. Assuming equal outcomes for different approaches, the remaining issue dominating the discussion will be cost-effectiveness, which remains to be solved. The future will show whether "it is no longer blood and guts, it is bits and bytes" [61].

Conflicts of interest

The authors have nothing to disclose.

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