REVIEW ARTICLE

Recent Advances in Pediatric Laparoscopy.

*** Abraham MK **Nasir AA**
*Dept. of Pediatric surgery Amrita Institute of Medical Sciences and Research center Kochi, India
**Division of Paediatric Surgery, University of Ilorin Teaching Hospital, Ilorin, Nigeria

Abstracts
Laparoscopic and thoracoscopy surgery in children has been described as a viable minimally invasive alternative to open surgery for many pediatric surgical conditions. With the goal of reducing the morbidity associated with open surgery, minimally invasive surgery in children is increasingly being performed as laparoscopic and thoracoscopic patients appear to be experiencing shorter hospital stays, decreased pain medication requirements, and the potential for improved cosmesis. This article provides an overview of recent advancement in laparoscopic, thoracoscopic and robotic-assisted laparoscopic surgery in children. Laparoscopic appears to be safe and effective in children for a wide range of ablative and reconstructive procedures. Conventional laparoscopic surgery is effective for ablative procedures, while robotic surgery may be ideally suited for reconstructive cases requiring
advanced suturing and dissection. Overall, more prospective studies are needed to study the long-term outcomes of minimally invasive surgery in pediatric patients, and the appropriate use of the available technology.

Key Words: Laparoscopy; Robotics;Thoracoscopic; Pediatrics; Advances.

Correspondence:
Mohan K Abraham,
Professor and Head of the Department,
Department of Pediatric surgery
Amrita Institute of Medical Sciences and Research centre
Amrita Lane, Elamakkara P.O., Kochi, India
Tel: +919847165614
mohanabraham@aims.amrita.edu

Introduction:
From the time studies showed that the catabolic response to trauma is directly proportional to intra operative trauma, attempts have been made to reduce this trauma. Where trauma of surgery itself was great, attempts were made to stage the procedures. Where trauma of access was more than the trauma of surgery itself, attempts were made to reduce the size of incision. Reduction in the size of incision also resulted in poor visibility and assessment of the pathological anatomy. Introduction of a viewing instrument into the peritoneal cavity circumvented these problems and errand the birth of minimal invasive surgery.

The beginning
Diagnostic laparoscopy was first described by Hans Christian Jacobeus[1] in 1910. Cortesi et al[2] described the first laparoscopy for undescended testis in 1976. Descriptions of laparoscopic appendectomy followed this[3]. The field of minimally invasive surgery (MIS) is the fastest growing area of surgical innovation. Each year as new techniques and tools are developed, more patients benefit from surgical procedures previously associated with a significantly more invasive approach[4].

The physiology:
Significant physiological changes occur during laparoscopy. Raised intra abdominal pressure leads to a collapse of the splanchnic vessels & reduction in venous return. Sakka el at reported that up to 12mm Hg is safe in small children undergoing laparoscopic herniotomy[5]. Carbondioxide up take is more pronounced in children due to smaller gap between peritoneum and capillaries and greater surface area of peritoneum in relation to body weight[6]. The absorption of CO2 leads to hypercapnia which increased intracranial pressure which is exaggerated in Trendelenburg position commonly used for laparoscopy. End Tidal CO2 monitoring during laparoscopy is therefore important to give early indication of hypercapnia. Position of the patient also has a bearing on the cardiac output. Tilting the head end up reduced the cardiac index[7].

Armamentarium:
Smaller scopes and instruments
The initial problem with pediatric laparoscopy was the

large size ports and instruments. Large size ports increased the trauma of surgery and were usually counterproductive. Smaller 3 mm ports were introduced to counter this problem. Laparoscopic instruments works like a lever with the fulcrum at the abdominal wall level. Force applied to the tip of the instrument is dependent on the ratio between the lengths of the instrument outside the patient to the length of the instrument inside the abdomen. The more the length of the instrument outside the patient greater will be the amplification of force transmitted to the tip of the instrument and the more the chances of inadvertent damage to tissues. These problems were sorted out with the introduction of 3 mm and 2 mm instruments of 20 cm length.

Hemorrhage control:
Hemorrhage control is important in laparoscopic surgery. It improves vision and makes dissection easy. However, electro coagulation has the problem of heat generation which could spreads and damage adjacent tissue. In monopolar diathermy the current enters the body at the tip of the instrument and leaves the body at the site of the cautery plate. Tissues in the line of current are at risk for damage. Narrower the tissue the more is the generation of heat and the more the risk of damage. This becomes an issue when you dissect tissues with a pedicle like in laparoscopic orchidopexy. Subsequently bipolar diathermy was introduced in which both the entry and exit points of the current are in the same instrument. This prevents the current from spreading to other tissues. However the application of current produces heat which spreads laterally causing damage. Ultra sonic scalpel was introduced then. This uses ultra sonic waves to produce coagulation. Lateral spread of heat is much lesser than bipolar or monopolar diathermy. It coagulates and cuts at the same time. Vessel sealing effect of this is superior to bipolar or monopolar diathermy and comparable to ligature which uses electrical current for sealing.

Video quality:
Initially a single chip camera was used. This had one charge-couple-device (CCD) which captured all the colors of the picture. Three chip cameras came in later. These have three CCDs one for each primary color. This resulted in much better color reproduction. Video quality was further enhanced by the introduction of high definition cameras.

Stereoscopic vision:
Normally we see the things with both the eyes. Eyes are situated about 64mm apart. Each eye captures the image from a different angle and sent to the brain. Brain fuses then into one single image which gives the depth perception. Depth perception is what is lacking in standard monoscopic cameras. Stereoscopic camera involves a telescope with twin vision channels. Pictures are send to two independent CCDs and then to processing units and monitor. This gives a real life like depth perception. Pediatric laparoscopy stands to gain a lot from this since the tissues are small and close together a proper depth perception will improve accuracy and speed up the procedure.

Recent advances
Major advances have occurred in pediatric laparoscopy. Most pediatric surgical training programs now include a curriculum in MIS. Many pediatric surgeons in the academic and private sectors are also finding creative ways to approach pediatric surgical problems from a minimally invasive perspective. These have had the greatest impact on advancement of this field[4]. These advances have occurred in the following areas: camera, instrumentation, thoracic surgery, abdominopelvic conditions, pediatric urology, in malignant condition and application to complex cases. This review focus on advances in thoracoscopy, laparoscopy , single port laparoscope and robotic laparoscopic surgery.

Pediatric thoracic surgery
Thoracoscopy was initially described for use in children to obtain pulmonary biopsy samples in the immunocompromised patient. With refinements in technique, development of better instrumentation, and advances in pediatric anesthesia, there are now many diagnostic and therapeutic indications for the use of thoracoscopy in children[8]. Minimally invasive pectus repair (MIPR) represents an ideal case study in the development, evaluation, and widespread acceptance of MIS for common pediatric surgical condition. Thoracoscopy has found wide spread use in the treatment of complicated empyema by thoracoscopic drainage and pleural decortications[4].

Congenital lung anomalies/Esophageal atresia
The largest experience with congenital lung anomalies (bronchopulmonary
sequestration, cystic adenomatoid malformation, and lobar emphysema) and foregut malformations (bronchogenic cysts and esophageal duplications) continues to exist within pediatric surgical practice[4]. Other complex surgical problem unique to the pediatric population is the repair of esophageal atresia and distal tracheoesophageal fistulas. Until recently, only a few reports, all from single institutions, had been published detailing individual surgeons' experiences with thoracoscopic repair of this anomaly [9-11].

Vascular pathology
Thoracoscopy has been used in pediatric pathology involving the great vessels within the chest. The minimally invasive approach can simplify the intraoperative procedure and the time for children undergoing aortopexy, vascular ring division, or patent ductus arteriosus (PDA) ligation.

Pediatric abdominopelvic laparoscopy
Gastroesophageal reflux disease
Over the past few years, laparoscopic fundoplication has become the treatment of choice for pediatric gastroesophageal reflux. Laparoscopic fundoplication in children imparts a faster return to normal feeding and activity, less postoperative pain, and a shorter hospital stay as in adult population [12].

Hepatobiliary surgery
Cholecystectomy is the most frequently performed laparoscopic procedure. The appropriate timing for laparoscopic cholecystectomy in the treatment of acute cholecystitis remains controversial. Siddiqui et al analysed all randomized clinical studies published between 1987 and 2006 comparing early versus delayed laparoscopic cholecystectomy for acute cholecystitis[13]. These meta-analysis data suggest that early laparoscopic cholecystectomy allows significantly shorter total hospital stay at the cost of a significantly longer operation time with no significant differences in conversion rates or complications [13]. In the last few years, there have been advancements in laparoscopic approaches to the treatment of congenital and acquired biliary diseases previously considered too complex for laparoscopy. Laparoscopic cystgastrostomy and Roux-en-Y cystjejunostomy are described in the treatment of pediatric pancreatic pseudocysts[14,15]. Several case series exist for the laparoscopic treatment of biliary atresia and choledochal cysts with acceptable outcomes [16]. Pediatric biliary disease also is treated with robotic techniques that may help to simplify complex biliary reconstruction procedures that are challenging for even experienced laparoscopic surgeons [17,18].

Gastointestinal surgery
MIS has been used to treat a variety of pediatric small intestinal pathology successfully, including Crohn's disease, Meckel's diverticulum, malrotation, and intussusceptions [19,20]. Some controversy exists in the use of laparoscopy to reduce intussusception when air enema has failed [21,22]. Two separate studies recently were published evaluating the safety and efficacy of laparoscopic reduction of intussusception [23,24]. Both groups reported success with laparoscopic reduction in 72% to 85% of cases in which enema reduction was unsuccessful. Laparoscopic-assisted bowel uresection was performed via the umbilical port site in cases in which a pathologic lead point was encountered [25].

Laparoscopic segmental resection and complete laparoscopic proctocolectomy are well described in the treatment of pediatric inflammatory bowel disease [19,26]. Technical details and clinical outcomes essentially are the same as those reported in adults. Meier and colleagues [27] recently published their experience with a completely minimally invasive approach in a cohort of pediatric patients. Their operative times were not significantly longer than an open approach; however, the investigators did report an increased number of postoperative obstructive complications at the ileostomy site, which they attributed to the use of a laparoscopic port site for the stoma.
The treatment of Hirschsprung's disease also has been revolutionized by MIS. What once was considered a three-stage operation consisting of a diverting colostomy, resection of the aganglionic bowel segment, and subsequent restoration of bowel continuity, now is largely replaced with a single-stage operation at most centers [28]. A laparoscopic Duhamel procedure was first described by Smith and colleagues [29]. Subsequently several techniques of laparoscopic-assisted Soave-type endorectal pull-through were described [30].
Laparoscopic repair of imperforate anus was first described by Georgeson and colleagues [31] in 2000. The proposed advantages include less pain, easier identification, and control of the fistula and a more accurate localization of the anus within the center of the sphincter complex. Because of its seemingly technical complexity and a lack of long-term outcome data, this procedure has been slow to gain acceptance amongst pediatric surgeons.The application of the laparoscopic approach seems most appropriate in boys with high or intermediate types of anorectal malformation. The advantage is in identification and control of rectourethral and rectovesical fistulae. In this regard, Vick and colleagues [32] published a series of six male neonates born at term who underwent a laparoscopic single-stage procedure for high imperforate anus malformations. The authors reported excellent visualization and control of fistulous connections in all cases and excellent overall results in their small series[32]. Long-term follow-up in this group of patients is expected to evaluate continence.
Recently, laparoscopic rectal pull-through technique was introduced in the management of cloacal anomalies. The technique was performed in 10 patients with persistent cloaca[33]. The authors conclude that laparoscopic rectal pull-through is a feasible, effective, and less traumatic approach for anorectoplasty in patients with persistent cloaca[33].

Urologic and gonadal abnormalities

Undescended testis and Varicocele

Pediatric urologists and surgeons have embraced MIS techniques for the diagnosis and treatment of certain benign and even certain malignant gonadal abnormalities. Radmayr and colleagues [34] reported the long-term results of a cohort of 84 children who underwent a primary or two-stage laparoscopic procedure for a total of 108 undescended testes. Their mean follow-up time for all patients was 6.2 years and none of the testes managed with a primary laparoscopic procedure became atrophic, and only two managed by a two-stage laparoscopic procedure atrophied during the follow-up period. Laparoscopic treatment of pediatric varicocele has also been performed with good results, but postoperative hydrocele formation is common, and approximately 10% to 15% of patients ultimately require additional surgical intervention [35,36].

Ovarian pathology

In female pediatric patients, laparoscopy can be diagnostic and therapeutic
in chronic abdominal pain caused by gonadal pathology. MIS is helpful
for early diagnosis and treatment of suspected ovarian torsion. Detorsion, oophoropexy or concomitant cystectomy can be performed as indicated[37].

Ureteropelvic Junction obstruction

Minimally invasive repair of ureteropelvic junction obstruction(UPJO) in infants and children has been reported by many groups as safe and efficacious.

Recently, Canon and colleagues [38] compared retroperitoneoscopic approach to the transperitoneal laparoscopic approach these two surgical procedures in a series of 49 consecutive patients, crossing over from the retroperitoneoscopic approach to the transperitoneal laparoscopic approach after the first 20 patients. They concluded that both procedures are safe and efficacious and should be performed in accordance with surgeon preference and individual experience level. Because laparoscopic retroperitoneal and transperitoneal pyeloplasties are difficult in infants for want of space Abraham et al [39] recently reported their experience with laparoscopic assisted retroperitoneum pyeloplasty in 38 children with UPJO. It was adduced to be safe and recommended for treating UPJ obstruction in infants, especially in small babies where laparoscopic pyeloplasty is difficult.

Hernia

Several techniques of laparoscopic hernia repair are described in the pediatric surgical literature. One recent report describes one center's experience with 300 hernia repairs using a subcutaneous endoscopically assisted ligation of the internal ring via a single-port technique [40]. The authors reported a recurrence rate of 4.3%, which improved with more experience.

Laparoscopy for pediatric malignancy.

Because MIS is well documented as safe and efficacious in the pediatric
population for surgical procedures in the thorax and abdomen, there may
be a significant role for MIS in the diagnosis and treatment of pediatric malignancy. The use of MIS to establish a definitive diagnosis in children who have suspected malignancy was first described by Holcomb and colleagues
[41] in 1995. To date, only small case series have been published evaluating the feasibility of MIS for resection of pediatric solid organ tumors, specifically neuroblastoma, and these techniques have been slow to gain acceptance among pediatric surgeons[42-44]. Metzelder and colleagues [45] published an intriguing study this year of a cohort of 307 children who had diagnosed malignancy at their institution that underwent minimally invasive treatment for their cancer. This report represents a valuable first step in evaluating the potential for MIS therapy in childhood cancer. Furthermore, the study further reinforced the feasibility and safety of MIS for diagnosis and staging of malignancy and evaluation of recurrent disease. In addition to reducing postoperative pain, the use of MIS may facilitate an earlier initiation of chemotherapy.

Laparoscopy for pediatric trauma

Traditionally, the application of laparoscopy in the presence of intra-abdominal traumatic injury has been limited by surgeon preference and familiarity and its ability to thoroughly evaluate injury; however, several studies recently have been published evaluating the applicability of MIS for trauma in children [46,47]. One potentially useful application of laparoscopy in the treatment of blunt trauma is in those cases in which free fluid is present but no solid organ injury can be identified. A report published by Feliz and colleagues [48] evaluated this situation in a series of 32 children. These children had significantly lower injury severity scores and higher Glasgow Coma Scale scores; they reported significantly fewer ICU admission days and shorter overall lengths of hospital stay.

Robotics:

Human beings are used to working with wrist joints which is not of much use in standard laparoscopy. Robot arms have wrist like joints with movements. Added on to this is the stereoscopic vision which makes laparoscopic surgery easier. However it lacks the sense of touch and tension. Breakage of threads while tying knots is a

common problem. Second problem is the large size ports which are not desirable for small children. Third problem is the costly disposables which in a developing country may cost more than the surgery itself. Each instrument costs 1000USD to 3000USD and can be used only 10 times. In contrast to conventional laparoscopy, the 3D high quality vision, the advanced instrument movements and the ergonomic position of the surgeon
should enhance surgical precision. Furthermore, robotics allows the specialised laparoscopic surgeon to operate in fields previously accessible only through large abdominal incisions. Thus, robotics overcomes the limitations of the laparoscopic techniques. Robotic surgery enables the surgeon to refine hand– eye coordination and provides the 3D views lost in
laparoscopic surgery giving greater precision for advanced laparoscopic procedures. The camera controlled by the surgeon, the instruments' small-scale movements and tremor elimination provide other major advantages[49].
Anderberg et al[49] in 2007 prospectively compared the first six fundoplications using the da Vinci-Surgical System operation robot from Intuitive Surgical to retrospective data from the latest six patients operated on at our centre using the open surgical procedure and the conventional laparoscopic technique are used as controls. The mean time for the robotic surgery operating procedure was longer than for the open surgery or the laparoscopic surgery. However, the operating time for the four latest robotic operations was the same as the
Operating time for the laparoscopic operations. They conclude that robotic surgery is comparable to laparoscopic surgery and better than open surgery with regard to the use of postoperative analgesics with morphine and postoperative hospital stay.

Single incision laparoscopic surgery (SILS)
SILS is also known as single port access surgery (SPA), single port incisionless conventional equipment-utilizing surgery (SPICES), single incision laparoscopic surgery (SILS), Single access endoscopic surgery (SAES), laparo-endoscopic single-site surgery (LESS), natural orifice transumbilical surgery (NOTUS), and one port umbilical surgery (OPUS). The early reports of this procedure occurred in 1990s. Esposito C reported on one trocar appendectomy in pediatric surgery in 1998[50]. Navarra G, Pozza E reported on SILS cholecystectomy in 1997[51]. A 20mm incision is made in the umbilicus through which ports are inserted. There are special ports that can be introduced through this incision. Port has 3 or 4 channels for camera and instrument introduction. GelPOINT system from Applied Medical, the SILS device from Covidien, the TriPort+, TriPort15 and QuadPort+ a from Advanced Surgical Concepts and the Uni-X from Pnavel are some of the ports available. The incision in the umbilicus can be used to introduce three separate ports when the technique is called single incision multiport technique. Since the number of instruments that can be used is limited, sutures that pass through the abdominal wall and tied to the organ of interest and back again through the abdominal wall is used for retraction of the organs. Conventional hand instruments can be used[52]. However the dissection becomes difficult since instruments are close together and triangulation is absent. There are special curved instruments that can be used for this purpose. Markar SR in his review found that complications and morbidity are same for standard multiport cholecystectomy and SILS cholecystectomy[53]. Laparo-endoscopic single-site (LESS) nephrectomy for benign renal disease in children is the single-port modification of laparoscopic nephrectomy, by which surgery can be performed in a virtually scar-free fashion through a single incision in the umbilicus [54]. Lee et al in a series of 11 pediatric patients ranging from infants to adolescents who have undergone successful single-port laparoscopic nephrectomy for benign disease reported no conversion to open surgery[55]. The LESS approach has been associated with improved cosmesis and a shorter recovery period compared with standard laparoscopic nephrectomy [54].

The future:
What is lacking in present day laparoscopic surgery is the sense of pressure and temperature. Once this can be incorporated into the instruments then surgeon will be able to feel the tissues and have a sense of pressure exerted as in open surgery. Works are already underway towards this. Ramu G and Ananthasuresh GK from Multidisciplinary and Multi-scale Devices and Design (M2D2) Laboratory Mechanical Engineering, Indian Institute of Science, Bangalore, India, presented a prototype in 14th National Conference on Machines and Mechanisms (NaCoMM09), NIT, Durgapur, India, December 17-18, 2009.
The next decade in pediatric health care likely will be characterized in part by an exponential growth of MIS. Innovative techniques are being used for increasingly complex and challenging operations in the pediatric population. Conventional laparoscopy will likely become the standard of care in procedures in pediatric surgery and urology. As the field of pediatric laparoscopic continues to grow, further trends toward "scarless" surgery, such as with LESS or single- site surgery, may continue as parents and patients seek minimally invasive options for their child's surgery.

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