Recent Advances in Minimal Invasive Surgery of Children

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Abstract: *There has been substantial progress in minimally invasive surgical techniques in children in past two decades. The work of Stephen Gans in the early 70's paved the way for mainstream laparoscopic procedures in adults and children. Refinements with modification and miniaturization of laparoscopic instruments have resulted in a substantial increase in the use of laparoscopy in many complex reconstructive procedures as well as in neonatal surgery. Recently, newer techniques like natural orifice trans-luminal endoscopic surgery (NOTES) and laparo-endoscopic single site surgery (LESS) have evolved, showing the changing trend towards scar-less surgery. Finally, one of the most important medical technological achievements of the 20th century is the introduction of the Da Vinci surgical system. This article outlines the development of minimal invasive surgery in children, giving an overview of various applications and techniques presently available.*

INTRODUCTION

Since the concept of laparoscopy gradually grew out of endoscopy, much of its history is shared with the development of endoscopy - which is a century old now. However, the introduction of this technique into the field of surgery has been a relatively recent development. During the 1960s and 1970s, laparoscopy was mainly part of gynecological practice. In the early 1970s, the pioneering work of Stephen Gans in pediatric endoscopy and peritoneoscopy was published[1, 2]. This accelerated the use of laparoscopy among general surgeons and gynecologists. In 1981, Kurt Semm[3] performed the first laparoscopic appendicectomy. Later, the first laparoscopic cholecystectomy was described by Muhe[4] in 1985.

On the other hand, applicability of laparoscopy in pediatric surgery was slower to develop than its adult counterpart. Several factors contributed to this slow evolution. The most important factor was lack of appropriate size instruments which increased risk of visceral injuries, prolonged the operating time and extended the learning curve. Further, reduced postoperative pain, decreased physiological stress and the advantage of smaller incision were underappreciated in children. Despite these multiple hurdles in minimal invasive surgery (MIS) of children progressed. Currently, the numbers of MIS procedures being performed in the pediatric age group are growing rapidly (Table1). Paramount to its success is advances in technology, availability of smaller sized instruments and better training. Also contributory are a good patient safety record, correct clinical application and satisfactory outcomes.

Laparoscopy and thoracoscopy are the commonest MIS procedures performed in various surgical disciplines. The feasibility and safety of a wide spectrum of these procedures in children have been confirmed by numerous studies[5, 6]. Laparoscopic surgery offers many advantages over standard open procedure including better visualization with magnification, faster recovery, reduced postoperative morbidity, less postoperative pain and better cosmesis[5]. Thus, pediatric patients represent a unique group who are likely to benefit from MIS. This article evaluates the current status of MIS in the pediatric surgical practice.

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Table 1: *Pediatric Surgical conditions which are now commonly done by laparoscopic surgery.*

Abdominopelvic Procedures
- Appendicectomy
- Cholecystectomy
- Fundoplication
- Gastrostomy
- Esophagomyotomy
- Meckel's diverticulectomy
- Small bowel resection
- Kasai Portoenterostomy
- Choledochal cyst resection
- Splenectomy
- Pull through procedure (Hirschprung's Disease & Anorectal malformation)
- Pyloromyotomy
- Duodenal atresia repair
- Ladd's procedure
- Adhesiolysis (for intestinal obstruction)

Thoracic Procedures (VATS)
- Repair of congenital diaphragmatic hernia
- Plication of diaphragm
- Repair of Esophageal atresia
- Decortication for Empyema
- Pleurodesis
- Lung biopsy and wedge resection
- Pulmonary lobectomy
- Resection of congenital cystic adenomatoid malformation
- Extra/Intra lobar sequestration resection
- Resection of mediastinal mass (anterior/posterior)
- Bronchogenic cyst resection
- Sympathectomy
- Thymectomy
- Ligation of Patent ductus arteriosus
- Repair of pectus deformities

Urogenital Procedures
- Inguinal hernia repair
- Fowler Stephens orchidopexy
- Varicocelectomy
- Pyeloplasty
- Partial/total nephrectomy
- Adrenalectomy
- Resection of utricle
- Extravesical ureteric reimplantation
- Ovarian cystectomy/Salpingo-oopherectomy
- Retroperitoneoscopic renal surgeries
- Pneumovesicoscopic procedure (ureteric reimplantation, bladder diverticulectomy)

Miscellaneous
- Obesity surgery
- Biopsy and Resection of various tumours (abdominal/thoracic)
- Evaluation of abdominal trauma

TECHNIQUES OF SAFER PNEUMOPERITONEUM IN INFANTS

Problems peculiar to pediatric MIS are smaller working space, non-availability of appropriate size instruments and laxity of the abdominal wall. All these factors cause difficulty in introducing a cannula with a sharp trocar, thereby increasing the risk of visceral injury. This has been overcome by taking extra care and by changing the angle of introduction to a more horizontal plane. Many surgeons prefer open technique by direct cut-down of the umbilical skin and fascia to introduce the cannula. Step trocar is another technique that was originally introduced in the late 1990s but is regaining popularity now[7,8]. In this procedure (Fig. 1), first a Veress needle with an expandable sheath is introduced through the abdominal wall. After removal of the Veress needle, a cannula with a blunt tipped trocar is introduced through the expandable sheath. After establishing pneumoperitoneum, additional cannulae for working instruments are inserted under direct vision. These cannulae are either disposable, reposable or re-usable. Alternatively, working instruments can be introduced directly through a stab incision in the abdominal wall without the use of a cannula. This direct method has the added advantage of cost saving apart from cosmesis.

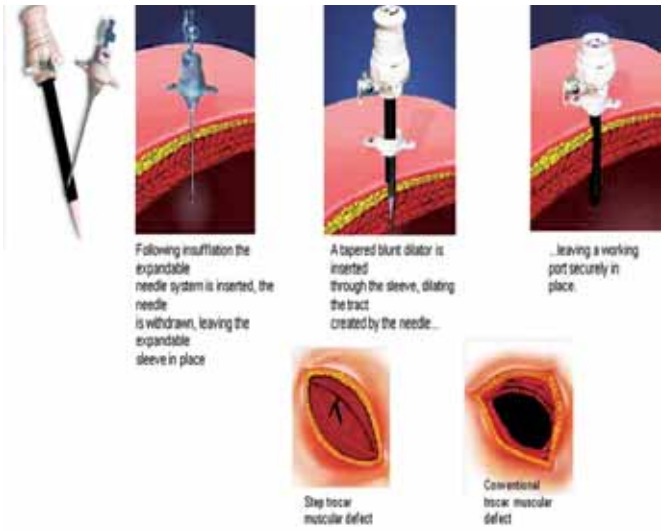

Figure 1: *Step-trocar technique (Verastep, Covidien)*

NEWER DEVICES FOR ENDOSUTURING

In advanced laparoscopic surgery of children, the most challenging and rate-limiting step is suturing and knot-tying. Intracorporeal suturing in children is a demanding task due to reduced work space, difficulties in tissue handling and poor needle-control. Automated suturing devices have greatly simplified the technique of endosuturing even for the novice[9,10]. *Endo Stitch* ™ and *SILS Stitch* ™ (Covidien) are 10 mm one-handed suturing devices that allow faster suturing by eliminating the need of uploading the needle each time as it is required in conventional laparoscopic suturing (Fig. 2). The needle can be passed easily from one jaw to other by closing the handles and flipping the levers. Further, *V-Loc* ™ (Wound Closure Reload, Covidien) which is used with *Endo Stitch* ™ has eliminated the need of knot tying by its uni-directional barb and loop design. By keeping the edges together, it also minimizes the challenge of maintaining adequate tension on the suture line during intracorporeal suturing.

Figure 2. *Endo Stitch devices (Covidien)*

APPLICATION OF LAPAROSCOPY IN VARIOUS ABDOMINAL PATHOLOGIES

During the past two decades the indications of pediatric laparoscopy have been expanded from diagnostic use and simple operations to complex hepatobiliary and urological reconstructive surgery. Diagnostic laparoscopy of children was started in 1970s for evaluation of non-palpable testes and patency of contralateral hernial sac. With refined instruments and techniques, it is now possible to evaluate the contralateral hernial sac through the ipsilateral hernia sac with the use of a 3 mm angled scope. Moreover diagnostic laparoscopy is being increasingly used for evaluation of abdominal pain, tumor staging, diagnostic biopsy and evaluation of penetrating abdominal trauma in children.

Laparoscopic appendicectomy was one of the earliest procedures[11] performed in children in 1991. In subsequent years, many new techniques were described including intra or extracorporeal resection of the appendix and transection of appendiceal stump by stapling or ligation devices. At our centre, we have been doing laparoscopic appendicectomy for both simple and complicated appendicitis without any significant difference in the complication rate as compared to the open procedure[12,13]. Laparoscopy has also been used to treat a variety of other small bowel pathologies such as intussusception, malrotation, Meckel's diverticulum and adhesive intestinal obstruction with good outcome. Laparoscopic partial or total splenectomy for a variety of non-traumatic pathologies like splenic cysts, hereditary spherocytosis, Thalassemia major and hypersplenism can be performed with less morbidity.

Laparoscopic cholecystectomy is now a well established procedure in children. Moreover, this approach is also used effectively and safely in the operations for more complex hepatobilliary conditions like biliary atresia and choledochal cyst. Recently, Ngyuen et al have reported 400 cases of choledochal cyst managed by laparoscopy and concluded that there is no significant difference between hepaticojejunostomy and hepaticoduodenostomy in terms of complications and outcome[14].

The management of Hirschsprung's disease has also been changed radically by laparoscopy. Instead of the previous standard three stage procedure comprising of a diverting colostomy, resection of the aganglionic segment and subsequent stoma closure, it is now managed by a laparoscopic-assisted single-staged primary pull through.

Similarly, a laparoscopic approach is gaining momentum in treatment of high and intermediate anorectal malformations. Easy identification and control of the fistula, accurate localization of the sphincter complex, single-stage repair and avoiding a diverting colostomy are the advantages of laparoscopic-assisted anorectoplasty operation done in the neonatal period. Preliminary results of several ongoing studies are promising[15].

Surgical management of gastroesophageal reflux disease (GERD) in children is now done preferentially by laparoscopic fundoplication[16]. Although all types of fundoplication including Nissen, Thal, Toupet and Boix-Ochoa can be done laparoscopically, in our experience Nissen's fundoplication has been found to be the best option. It can be performed safely with a concurrent gastrostomy button insertion in neurologically impaired children with associated feeding difficulties. Since this vulnerable group of children has increased morbidity due to their associated systemic illness, there have been efforts to evolve less invasive antireflux techniques like endoscopic fundoplication and radiofrequency ablation for Barrett's esophagus.

ENDOSCOPIC FUNDOPLICATION

This newer technique of trans-oral incisionless fundoplication has shown promising results in adults and children with GERD[17]. It may be a feasible option in complex re-operative cases and in patients with severe co-morbidities such as neurological impairment. This procedure is performed by using a special endoscopic surgical device (EsophyX, Endogastric Solutions), which is inserted into the esophagus per orally and positioned at cardioesophageal junction (Fig. 3). A full thickness tissue fold at the gastroesophageal junction is retracted, wrapped and anchored using multiple fasteners across the tissue to complete the plication and hence creating a tight 3-5 cm valve enveloping the distal esophagus below the diaphragm. Currently this procedure can only be performed in older children (>25 kg) on account of the size of the device.

MIS IN PEDIATRIC UROLOGY

Indications of laparoscopy in pediatric urology have evolved from diagnostic to ablative, and recently, to reconstructive procedures. Apart from the original application for localization of non-palpable testis, many centres are performing more advanced laparoscopic procedures in infants and children[18,19]. Many surgeons prefer the retroperitoneoscopic approach to perform various upper urinary tract operations like partial or total nephrectomy and pyeloplasty. This approach has lesser risk of abdominal organ injury and bowel adhesions compared to the laparoscopic approach as it avoids the peritoneal cavity.

In female children, laparoscopy can be used in the diagnosis and treatment of chronic abdominal pain caused by gonadal pathologies. Laparoscopic-assisted ovarian cystectomy with preservation of ovary has become the standard approach in management of ovarian cysts[20]. Surgical management of vesico-ureteric reflux is now possible with laparoscopic and pneumovesicoscopic approach. Lakshmanan et.al. have reported a 100 % success rate with extravesical Lisch Gregor technique for refluxing ureters[21].

PNEUMOVESICOSCOPY

Pneumovesicoscopy is an alternative minimally invasive approach to perform various urological procedures in children. The bladder is insufflated with CO_2 to introduce three trocars in the cavity under cystoscopic control. The first midline 5 mm trocar is introduced for the telescope near the dome of bladder followed by left and right, 3 or 5 mm trocars, inserted through the anterolateral wall as working channels. Then the required surgery can be carried out in the usual way from inside the bladder. Valla et.al. reported 92% success rate in 72 cases of vesicoureteric reflux managed by pneumovesicoscopic ureteric reimplantation[22]. This approach is also used effectively for the management of bladder diverticulum and calculi. According to published reports, the results of pneumovesicoscopic reimplantation

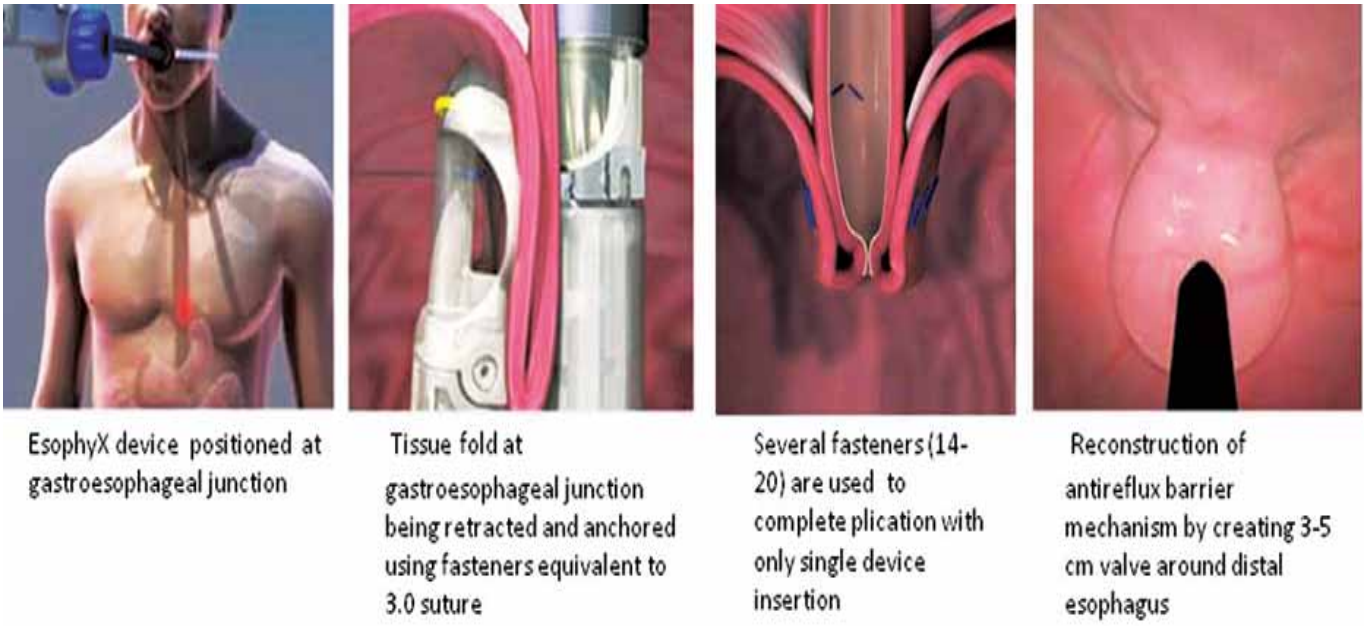

Figure 3. *Endoscopic fundoplication (EsophyX, Endogastric solution)*

are similar to open surgery in appropriately selected patients. Children under one year and huge megaureter should be excluded.

CHALLENGES OF MIS IN NEONATES AND INFANTS

Laparoscopy in neonates has evolved even more slowly when compared to other age groups. Extremely small size of the abdominal cavity causes increased risk of visceral injury and technical difficulty of maneuvering oversized instruments (Fig.4). Miniaturization of instruments, improved energy sources, evolution of low flow CO_2 insufflator and tissue sealing devices such as Ligasure (Valley Lab) and harmonic scalpel (Ethicon) have made laparoscopy safer in various neonatal conditions like pyloric stenosis, esophageal atresia, congenital diaphragmatic hernia, duodenal atresia, inguinal hernia, and ovarian pathologies[23]. Published data[24-36] on laparoscopic surgery of neonates and infants is summarized in Table 2. Physiological effects of CO_2 insufflation and raised intra-abdominal pressure are still a source of concern in neonatal laparoscopy. Although neonates are sensitive to CO_2 absorption and can develop respiratory acidosis, published data suggests that intra-abdominal pressures of 8 to 10 mm Hg are tolerated well. Some of these difficulties can be overcome by an experienced team of anesthesiologists.

Figure 4: *A Comparison of instrument (left- laparoscope, right-SILS port) and patient size*

VIDEO-ASSISTED THORACOSCOPIC SURGERY (VATS) IN CHILDREN

The first use of VATS dates back to the mid-1970s for diagnostic exploration and biopsy of intrathoracic lesions in infants. Now, many complex diagnostic and therapeutic procedures are performed thoracoscopically[37]. General anesthesia with single-lung ventilation

Table 2: *Selected data from literature on MIS procedures in neonates and infants*

Author (year)	MIS procedure	Study Design	n	Outcome
Rothenberg (2012)	Repair of Esophageal atresia ± TEF	retrospective	49 (TS)	Operative time- 50 to 120 mins Conversion rate 2%, anastomotic leak 4% Need of post-operation dilatation -30%
Rothenberg (2011)	Lobectomy for cystic lung lesions	retrospective	75 (TS)	Operative time: 45-225 mins conversion-1 case, hospital stay 1-5 days
Tsao (2011)	Congenital diaphragmatic hernia repair	prospective	114(O) 151(L)	High survival rate in MIS group Higher recurrence rate with thoracoscopic repair
Shah (2010)	Nissen's Fundoplication +/- gastrostomy	retrospective	122 (L)	Conversion rate: 7% Operative time: 112+/-46 mins, Recurrent reflux: 2.5%, other complications: 2.5%
Oomen (2012)	Pyloromyotomy	Meta-analysis	255 (O) 247 (L)	Shorter time to full feed and hospital stay in Laparoscopy group No difference in complication rate
Kay (2009)	Duodenal atresia repair	retrospective	17 (L)	No conversion, no complications
Liem (2010)	Biliary atresia repair	retrospective	11 (L)	No conversion, good early outcome
Hagendoorn (2011)	Ladd's Procedure of Malrotation	retrospective	37 (L)	Conversion rate 25%, Recurrence rate 19%
Li (2012)	Repair of intestinal atresia/stenosis	retrospective	35 (LA)	excellent early outcome with good cosmetic results
Tang (2012)	Endorectal pull through for Hirschprung's Disease	retrospective	218 (LA)	Median operative time: 176 mins Conversion rate: 1% Anastomotic leak :1.5%, late postoperative complications:13%
De Vos (2011)	Anorectoplasty for ARM	retrospective	20 (LA) 19(O)	Safe and feasible Laparoscopy group had slightly more complications
Turial (2011)	Inguinal hernia repair	retrospective	147 (L)	Safe and feasible, recurrence:2%, high testicle: 4%
Schenkman (2008)	Transumbilical extracorporeal ovarian cystectomy (LATEC)	retrospective	12(LA) 8(O)	Shorter operative time and faster recovery in LATEC group

LA - Laparoscopy-assisted, L - Laparoscopy, O-Open surgery, ARM - Anorectal malformation, TEF - Tracheo-esophageal Fistula, TS - Thoracoscopy

is essential to collapse the ipsilateral lung for thoracoscopy. Apart from simple procedures like diagnostic thoracoscopy, lung biopsy, decortication and pleurodesis, other complex therapeutic procedure have also been performed. These include repair of esophageal atresia, diaphragmatic hernia, pulmonary and mediastinal mass resections, thoracic sympathectomy, thymectomy and pectus repair.

GROWING EXPERIENCE WITH THORACOSCOPIC ESOPHAGEAL ATRESIA REPAIR

Thoracosopic repair of esophageal atresia has come a long way since it was first attempted successfully in 1999. Since then, there have been many reports from various centers. Recently Rothenberg reported 43 cases of esophageal atresia repaired thoracoscopically with good outcome (Table 2). The greatest advantage of thoracoscopic approach is avoiding a posterolateral thoracotomy and its associated sequelae of scoliosis and shoulder girdle weakness. It provides better exposure and visualization compared to open thoracotomy. Rothenberg recommends the use of modified prone position (right side elevation by 30-45 degree) for good exposure of the posterior mediastinum. In this position, the lung is retracted anteriorly by gravity thus obviating the need for lung retraction. Another advantage of thoracoscopic repair is that there may be less tension on the esophageal ends, thus allowing longer gaps to be anastomosed without tearing. Proper placement of ports to improve visualization and precise suturing is imperative.

REPAIR OF DIAPHRAGMATIC HERNIA: THORACOSCOPY VERSUS LAPAROSCOPY

Both thoracoscopic and laparoscopic approaches have been described for the repair of congenital diaphragmatic hernia[38]. Laparoscopic approach has the advantages of complete examination of the abdominal viscera, secure suturing without the risk of visceral injury and an easy conversion if needed. However, working space is significantly reduced, especially after reducing the contents of the hernia. It also requires persistent CO_2 insufflation. On the other hand, thoracoscopy allows better working space, easier reduction and intermittent CO_2 insufflation. But the examination of abdominal viscera is limited and there is always a potential risk of abdominal viscera injury during suturing of the defect. According to Shah et al[39], thoracoscopy is preferred for neonatal Bochdalek hernias whereas Morgagni hernias are better managed by laparoscopy. Either approach can be used successfully for infants and children with Bochdalek hernias.

ROLE OF LAPAROSCOPY IN PEDIATRIC ONCOLOGY

There is a significant role for minimally invasive procedures in the diagnosis and treatment of pediatric malignancies, which was first described by Holcomb et.al.[40] in 1995. Due to prevailing controversies regarding safety and appropriateness of laparoscopy in the setting of malignancy, this technique was slow to gain acceptance among pediatric surgeons.

In 2008, Metzelder et al[41] published a large series of pediatric cancers treated with MIS. A minimally invasive approach for biopsy was attempted in 90 cases with cancer and successfully accomplished in 77% of operations with an accuracy of 98%. Ablative surgery was attempted in 35 cases (24-abdominal/retroperitoneal, 11- thoracic). The conversion rate was more than 30% in both laparoscopic and thoracoscopic cases. The reason for conversion was limited visibility and bleeding. There were no port site recurrences. Their data confirmed that MIS is a safe and reliable diagnostic tool for pediatric abdominal and thoracic malignancies. Although its feasibility in ablative surgery remains limited, it may improve with meticulous patient selection.

BARIATRIC SURGERY: LAPAROSCOPIC ADJUSTABLE GASTRIC BANDING

With the growing problem of pediatric obesity, there has been a strong interest to develop laparoscopic bariatric surgical treatment. The introduction of laparoscopic adjustable gastric banding (Lap-Band) has a potential advantage in pediatric patients especially as it avoids the chronic nutritional derangement of traditional gastric bypass procedures. The Lap-Band system is an adjustable and reversible gastric band which can be placed around the upper stomach laparoscopically. It reduces the gastric capacity and restricts the amount of food intake (Fig. 5). The band is connected to an access port, which is located under the skin. By injecting saline solution through the port the diameter of the band can be adjusted to achieve a controlled rate of weight loss. There is no doubt that the Lap-Band is a simpler procedure with less surgical risk as compared to other forms of bariatric surgery (gastric bypass, sleeve gastrectomy etc.). However, it may require significant postoperative manipulation and has a slightly higher re-operative rate. Safety and efficacy of this procedure has been assessed in various published reports. One prospective study[42] of 73 children with gastric banding has shown excellent results with 70% resolution of obesity-related co-morbidity.

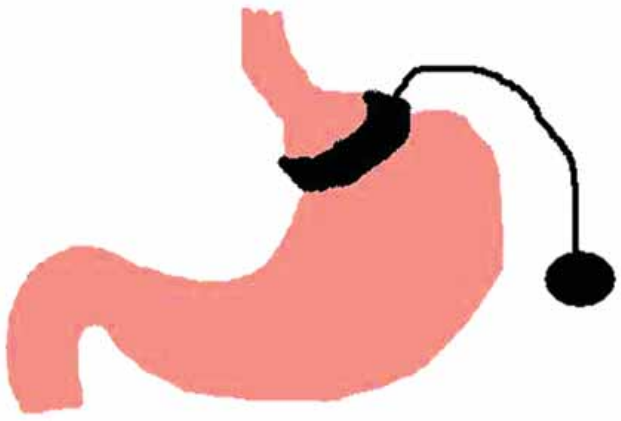

Figure 5. *Principle of adjustable gastric band with subcutaneous port*

SCAR-LESS SURGERY (NOTES AND SILS)

Recently, there has been a remarkable interest in reducing the number of ports needed for endoscopic surgery of children. Natural Orifice Trans-luminal Endoscopic Surgery (NOTES) was developed for scarless surgery but did not gain popularity due to its potential risk of visceral injuries, adhesions and infections. Lack of success of NOTES seems to have been replaced by an interest in single incision laparoscopy (SILS). It is now possible to perform most of the pediatric surgical procedures using SILS[43,44]. Multiple acronyms have been used to describe single port surgery which includes SILS (single incision laparoscopic surgery), LESS (laparo-endosopic single-site surgery), SPS (single port surgery), SIMPLE (single incision multiple

puncture laparo-endoscopic surgery), SIPES (Single incision port laparoscopic surgery), OPUS (one port umbilical surgery), SPA (single port access), and SSULS (single site umbilical laparoscopic surgery).Noticeably, at recent international endoscopic meetings (IPEG, SAGES etc), more studies are comparing conventional laparoscopic techniques with SILS in pediatric surgical conditions. Single-port assisted technique can be performed through a single incision and multichannel port or with multiple direct stab incisions. The main problems with single port surgery are loss of triangulation, clashing of instruments and lack of maneuverability. Some of these difficulties can be overcome with the use of new access devices and new pre-bent or articulating instruments. But it must be borne in mind that the use of all these new instruments has a significant learning curve. Despite all limitations, single port surgery is rapidly evolving and gaining popularity due to high acceptance among patients.

MAGNET-ASSISTED LAPAROSCOPY

Several modifications in ports and instruments are being done to overcome the limitation of poor ergonomics and insufficient triangulation of SILS. One such recent development is the introduction of magnet-assisted laparoscopic surgery. This technology can be used as an adjunct to conventional laparoscopy as well as SILS. It involves the use of specialized magnetic graspers which are introduced into the abdominal cavity through a 12 mm cannula and attached to an intra-abdominal organ with the help of specialized forceps. By repositioning the external magnet on the abdominal wall (mounted on a self-retaining articulating arm) these intra-abdominal magnetic graspers can be controlled to provide traction on the desired organ during surgery (Fig. 6). Thus, this technique can reduce the need of additional ports for retraction. Most operations can be performed with the use of single magnetic grasper. Learning to control a single magnet is easier than using multiple magnets because multiple magnets have a tendency to clump together. There has been no report of untoward effects on patient physiology or interference with any electronic equipment during surgery due to the presence of a magnetic field. The major drawback of magnet-assisted laparoscopic surgery is the need of special magnetic instruments that are not widely available currently.

This technique has been shown to be safe and effective in pediatric SILS as it improves exposure, triangulation and the ergonomics of surgery. In 2011 Benjamin Padilla[45] and colleagues reported their experience with 44 magnet assisted laparoscopic procedures performed for various pediatric surgical conditions. There were no major intra-operative complication and the preliminary results are encouraging.

ROBOTICS AND ALTERNATIVE TECHNOLOGIES

Role of laparoscopy in complex reconstructive procedures is still limited and is associated with a longer operating time as compared to open surgery. Some limitations of the currently available equipments include loss of haptic feedback, loss of hand-eye coordination, loss of dexterity and loss of depth perception. Moreover, the fulcrum effect and restricted degree of motion can further compromise its effectiveness. In an effort to overcome some of these restrictions, novel approaches including Robotic surgical technology were developed. In 2006, Society of American Gastrointestinal and Endoscopic Surgeons/Minimally Invasive Robotic association (SAGES/MIRA) held a consensus meeting addressing the application

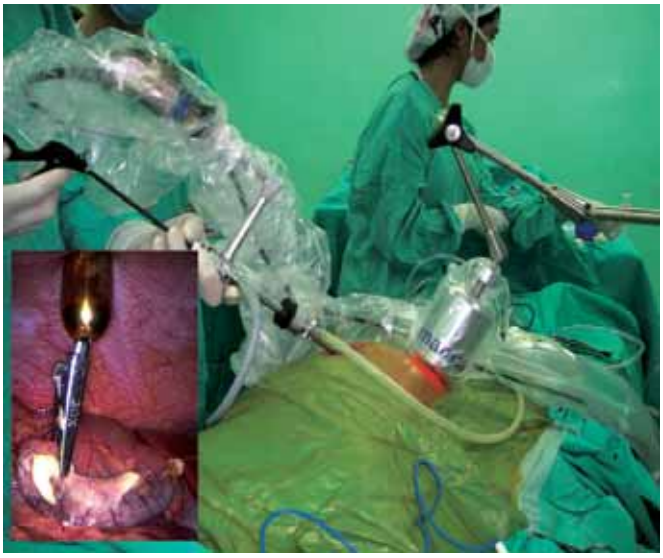

Figure 6. *Magnet-assisted laparoscopic surgery with internal magnetic grasper (lower left) and external magnet mounted on a self-retaining retractor (Photo credit: Marcelo Martinez-Ferro, Fundacion Hospitalaria Children's Hospital, Buenos Aires)*

and credentialing of Robotic surgery in pediatric age group. Since then, many robotic procedures have been performed at various centers worldwide[46]. Although operations that involve complex suturing or dissection are ideal for the Da Vinci robot, it is good for young surgeons to begin with simple procedures. The most significant advancement made in robotic surgical technology is the addition of high resolution three dimensional visions, dexterous wrist like movement capabilities and tremor filtration with geometric scaling of movements. The biggest obstacle to using the Da Vinci robot is the high cost of the robot and semi-dispososable equipments. With reducing cost this technology may find more application in pediatric surgery.

The boundaries of minimally invasive surgery have greatly expanded with the development of the robotic surgical system. The development of more advanced computer and robotic technology has given rise to the concept of tele-collaboration. This has been associated with several other concepts like tele-evaluation (audio-video tele-conferencing, tele-mentoring (teaching and supervision by remotely located expert surgeons), tele-monitoring, tele-manipulation and tele-surgery. The first successful telesurgery on a human patient was performed in 2001 (operation Lindberg)[47], which opened the way for a wide ranging application of tele-surgical technology. Training and assisting surgeons, treating injured soldiers in battlefields, performing surgical procedures in space, and collaborating and mentoring by surgeons around the globe are some of the potential advantages of tele-surgery. It is expected that as tele-communication networks and robotic technology improve, many of the limitations associated with latency and bandwidth of data can be overcome.

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REFERENCES

1.) Gans SL, Berci G. Peritoneoscopy in Infants and Children. J Pediatr Surg 1973; 8: 399 - 405.

2.) Gans SL, Berci G. Advances in Endoscopy of Infants and Children. J Pediatr Surg 1971; 6:199 - 233.
3.) Semm K: Endoscopic appendectomy. Endoscopy 1983; 15: 59 - 64
4.) Muhe E. Long-term follow-up after laparoscopic cholecystectomy. Endoscopy 1992; 24: 754-758.
5.) Durkin ET, Shaaban AF. Recent advances and controversies in Pediatric Laparoscopic Surgery. Surg Clin North Am 2008; 88: 1101 - 1119.
6.) Georgeson KE, Owing E. Advances in minimally invasive surgery in children. Am J Surg 2000; 180: 362 - 364.
7.) Feste JR, Bojahr B, Turner DJ. Randomized Trial Comparing a Radially Expandable Needle System with Cutting Trocars. JSLS 2000; 4: 11–15. (Correction in: JSLS 2000; 4(2): 184)
8.) Venkatesh R, Sundaram CP, Figenshau RS, et al. Prospective Randomized Comparison of Cutting and Dilating Disposable Trocars for Access During Laparoscopic Renal Surgery. JSLS 2007; 11: 198–203.
9.) Omotosho P, Yurcisin B, Ceppa E et al. In vivo assessment of an absorbable and non-absorbable knotless barbed suture for laparoscopic single-layer enterotomy closure: a clinical and biomechanical comparison against non-barbed suture. J Laparoendosc Adv Surg Tech A 2011; 21: 893 - 897.
10.) Gopel T, Hartl F, Schneider A, Buss M, Feussner H. Automation of a suturing device for minimally invasive surgery. Surg Endosc 2011; 25: 2100 - 2004.
11.) Ure BM, Spangenburger D, Hebebrand E, et al: Laparoscopic surgery in children and adolescents with suspected appendicitis: Results of medical technology assessment. Eur J Pediatr Surg. 1991; 2: 336-340.
12.) Rai R, Chui CH, Sai Prasad TR et al. Perforated appendicitis in children: benefits of early laparoscopic surgery. Ann Acad Med Singapore 2007; 36: 277 - 280.
13.) Sai Prasad TR, Chui CH, Jacobsen AS. Laparoscopic appendicectomy in children: A trainee's perspective. Ann Acad Med Singapore 2006; 35: 694 - 697.
14.) Liem NT, Pham HD, Dung LA et al. Early and Intermediate Outcomes of Laparoscopic Surgery for Choledochal Cysts with 400 Patients. J Laparoendosc Adv Surg Tech A. 2012; 22: 599-603.
15.) Al-Hozaim O, Al-Maary J, AlQahtani A. Laparoscopic-assisted anorectal pull-through for anorectal malformations: a systematic review and the need for standardization of outcome reporting. J Pediatr Surg 2010; 45: 1500 - 1504.
16.) Rothenberg SS. Experience with 220 consecutive laparoscopic Nissen fundoplication in infants and children. J Pediatr Surg 1998; 33: 274 - 278.
17.) Chen S, Jarboe MD, Teitelbaum DH. Effectiveness of a transluminal endoscopic fundoplication for the treatment of pediatric gastroesophageal reflux disease. Pediatr Surg Int 2012; 28: 229 - 234.
18.) Chui CH, Jacobsen AS. Laparoscopy in the evaluation of the non-palpable undescended testes. Singapore Med J 2000; 41: 206 - 208.
19.) Esposito C, Valla JS, Yeung CK. Current indications for laparoscopy and retroperitoneoscopy in pediatric urology. Surg Endosc. 2004; 18: 1559 - 1564.
20.) Mayer JP, Bettolli M, Kolberg-Schwerdt A et al. Laparoscopic approach to ovarian mass in children and adolescents: already a standard in therapy. J Laparoendosc Adv Surg Tech A 2009; 19 (Suppl 1): s111 - s115.
21.) Lakshmanan Y, Fung LC. Laparoscopic extravesicular ureteral reimplantation for vesicoureteral reflux: recent technical advances. J Endourol. 2000; 14: 589 – 593.
22.) Valla JS, Steyaert H, Griffin SJ, Transvesicoscopic Cohen ureteric reimplantation for vesicoureteral reflux in children: a single-centre 5-year experience J Pediatr Urol 2009; 5: 466 - 471.
23.) Ponsky TA, Rothenberg SS. Minimally invasive surgery in infants less than 5 kg: experience of 649 cases. Surg Endosc 2008; 22: 2214 - 2219.
24.) Rothenberg SS. Thoracoscopic repair of esophageal atresia and tracheo-esophageal fistula in neonates: evolution of a technique. J Laparoendosc Adv Surg Tech A 2012 ;22:195 - 199.
25.) Rothenberg SS, Kuenzler KA, Middlesworth W et al. Thoracoscopic lobectomy in infants less than 10kg with prenatally diagnosed cystic lung disease. J Laparoendosc Adv Surg Tech A 2011; 21:181-184.
26.) Tsao K, Lally PA, Lally KP. Congenital Diaphragmatic Hernia Study Group. Minimally invasive repair of congenital diaphragmatic hernia. J Pediatr Surg 2011; 46:1158-1164.
27.) Shah SR, Jegapragasan M, Fox MD, et al. A review of laparoscopic Nissen fundoplication in children weighing less than 5kg. J Pediatr Surg 2010; 45:1165-1168.
28.) Oomen MW, Hoekstra LT, Bakx R et al. Open versus laparoscopic pyloromyotomy for hypertrophic pyloric stenosis: a systematic review and meta-analysis focusing on major complications. Surg Endosc 2012; 26: 2104-2110.
29.) Kay S, Yoder S, Rothenberg S. Laparoscopic duodenoduodenostomy in the neonate. J Pediatr Surg 2009; 44:906-908.
30.) Liem NT, Son TN, Quynh TA, et. al. Early outcomes of laparoscopic surgery for biliary atresia. J Pediatr Surg 2010; 45:1665-1667.
31.) Hagendoorn J, Vieira-Travassos D, van der Zee D. Laparoscopic treatment of intestinal malrotation in neonates and infants: retrospective study. Surg Endosc 2011; 25:217-220.
32.) Li B, Chen WB, Wang SQ et al. Laparoscopy-assisted surgery for neonatal intestinal atresia and stenosis: a report of 35 cases. Pediatr Surg Int 2012; 28:1225-1228.
33.) Tang ST, Wang GB, Cao GQ et al. 10 years of experience with laparoscopic-assisted endorectal Soave pull-through procedure for Hirschsprung's disease in China. J Laparoendosc Adv Surg Tech A 2012; 22:280-284.
34.) De Vos C, Arnold M, Sidler D et al. A comparison of laparoscopic-assisted (LAARP) and posterior sagittal (PSARP) anorectoplasty in the outcome of intermediate and high anorectal malformations. S Afr J Surg 2011; 49:39-43.
35.) Turial S, Enders J, Krause K et al. Laparoscopic inguinal herniorrhaphy in babies weighing 5 kg or less. Surg Endosc 2011; 25:72-78.
36.) Schenkman L, Weiner TM, Phillips JD. Evolution of the surgical management of neonatal ovarian cysts: laparoscopic-assisted transumbilical extracorporeal ovarian cystectomy (LATEC). J Laparoendosc Adv Surg Tech A 2008; 18:635-640.
37.) Oak SN, Parelkar SV, Satishkumar KV et al. Review of video-assisted thoracoscopy in children. J Minim Access Surg 2009; 5:57-62.
38.) Gomes Ferreira C, Reinberg O, Becmeur F et al. Neonatal minimally invasive surgery for congenital diaphragmatic hernias: a multicenter study using thoracoscopy or laparoscopy. Surg Endosc 2009; 23:1650-1659.
39.) Shah SR, Wishnew J, Barsness K, et al. Minimally invasive congenital diaphragmatic hernia repair: a 7-year review of one institution's experience. Surg Endosc 2009; 23:1265-1271.
40.) Holcomb GW, Tomita SS, Haase GM. Minimally invasive surgery in children with cancer. Cancer 1995; 76:121-128.
41.) Metzelder ML, Keubler JF, Shimotakahara A. Role of diagnostic and ablative minimally invasive surgery for pediatric malignancies. Cancer 2007; 109: 2343 - 2348.
42.) Nadler EP, Youn HA, Ren CJ, Fielding GA. An update on 73 US obese pediatric patients treated with laparoscopic adjustable gastric banding: co-morbidity resolution and compliance data. J Pediatr Surg 2008; 43: 141 - 146.
43.) Prashanth P Rao, Pradeep P Rao, Sonali Bhagwat. Single-incision laparoscopic surgery - current status and controversies J Minim Access Surg 2011; 7: 6 -16.
44.) Hansen EN, Muensterer OJ, Georgeson KE, et al. Single incision pediatric endosurgery: Lessons learned from our first 224 laparoendoscopic single-site procedures in children. Pediatr Surg Int 2011; 27: 643 - 648.
45.) Padilla BE, Dominguez G, Millan C. The use of magnets with single-site umbilical laparoscopic surgery. Semin pediatr surg 2011; 20: 224 - 231.
46.) Meehan JJ, Sandler A. Pediatric robotic surgery: A single-institutional review of the first 100 consecutive cases. Surg Endosc 2008; 22: 177 - 182.
47.) Marescaux J, Leroy J, Rubino F, et al. Transcontinental Robot Assisted Remote Telesurgery: Feasibility and Potential Applications. Ann Surg 2002; 235: 487 - 492.

Literature Review

Outcomes with Split Liver Transplantation are Equivalent to those with Whole Organ Transplantation

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Split liver transplantation is an excellent option for expansion of the donor organ pool. However, reports of increased morbidity in split liver recipients may limit use of this technique. This was a single center retrospective analysis investigating split liver transplantation. Between August 1, 1995 and March 30, 2012, 53 of 1,261 (4.2%) recipients received split liver grafts. The 1-, 5-, and 10-year patient and graft survivals in adult recipients of split grafts were 95.5%, 89.5%, and 89.5%, respectively. Survival was similar to that of whole organ recipients (p = 0.15). Twenty-three adults received split grafts: 18 (78%) were right trisegment grafts, 4 (17.4%) were right lobes, and 1 (4.3%) was a left lobe. The mean cold ischemic time was 5.7 hours (±2.4 hours [SD]) and warm ischemic time was 36 minutes (±5.5 minutes). Four (17%) recipients required hepatic artery reconstruction; 5 (21.7%) required a caval-venous patch, and 5 (21.7%) had Roux-en-Y reconstruction of the bile duct. No venous conduits were required. Thirty children received split grafts (median age 1.2 years, range 0.1 to 16.4 years) and had a median weight of 8.6 kg (range 3.6 to 45 kg). Pediatric split 1-, 5-, and 10-year overall and graft survival rates were 96.7%, 80.0%, 80.0%, and 93.3%, 76.8, and 76.8%, respectively. Complications included retransplantation in 3 (10.0%), bile leak in 5 (16.7%), hepatic arterial thrombosis in 2 (6.7%), bowel perforation in 2 (6.7%), and bleeding in 2 (6.7%). The mean donor age was 22.4 months (±8.9) months and body mass index was 22.8 kg/m(2) (±3.3 kg/m(2)). We demonstrated excellent outcomes in adult and pediatric recipients using carefully selected donors for liver splitting. We recommend escalation of the use of split liver transplants to expand the donor pool for cadaveric liver transplantation.