

# Laparoscopic Surgery in Newborns and Infants: An Update

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## Abstract

Development of laparoscopic or minimally invasive surgery (MIS) in infants and children has taken a tremendous pace over the past decade. With the availability of appropriately sized fine instruments tailored made for small paediatric patients, together with significant improvement in surgical technique and anaesthetic experience, a wide range of operations can now be performed by the laparoscopic approach even in small newborn infants. These include a whole spectrum of gastrointestinal tract operations, herniotomy and even more complicated thoracoscopic and laparoscopic reconstructive procedures, e.g. oesophageal anastomosis for oesophageal atresia and surgery for choledochal cyst and biliary atresia. Evidence so far suggests that minimal access surgery results in a more rapid recovery, shorter hospital stay and much better wound cosmesis. The advent of MIS has revolutionised the overall management strategy for certain diseases such as Hirschsprung's disease, imperforate anus and gastro-oesophageal reflux. There is no age limit to its application. With further improvement in technology and advances in surgical experience and skills, there is little doubt that laparoscopic surgery would gain a much wider acceptance and become the treatment of choice in place of conventional open surgery for the great majority of surgical conditions in infants and young children in this new millennium.

**Key words** Infant; Laparoscopy; Newborn

## Introduction

The development of laparoscopic surgery, or "keyhole" surgery, has been tremendous since the late 80's. Although its application in infants and children has in general been lagging behind compared with that in adults, it has taken an explosive pace since the mid-90's.<sup>1,2</sup> Use of the laparoscope in children, however, is not new. Gans had first published his experience on peritoneoscopy in infants and children as early as 1970's, well before the landmark development of laparoscopic cholecystectomy in adults in

1987.<sup>3</sup> Nevertheless, this early work on peritoneoscopy was limited mainly to diagnostic purpose. This may be partly due to the uncertainty about the benefit of laparoscopic surgery in children. Traditional paediatric surgeons always argue that they have already used sufficiently small wounds for open surgery, without taking into consideration the struggle to operate through these "small" wounds. Furthermore, the growth factor in children would render an initially small wound, e.g. an upper quadrant incision for a pyloromyotomy becoming a much bigger and rather unsightly scar in later life. There was also earlier scepticism regarding the potential benefits of minimally invasive surgery, viz. smaller wounds, less post-operative pain, earlier mobilisation and return to normal activities, that were observed in adults might be less apparent in infants and young children, although more recent studies have provided mounting evidence that the paediatric population probably benefits as much from minimally invasive surgery (MIS) as their adult counterparts. In addition, earlier return to normal activities or schooling for the children may actually

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free the parents and allow an earlier return to normal work and productivity.

Initial development of MIS in infants and young children in the earlier 90's has been significantly restricted by the unavailability of appropriate paediatric-sized laparoscopic instruments. Pioneers in paediatric laparoscopic surgery had to struggle to operate with large and long adult-sized instruments, and submit to the associated unfavourable working ergonomics. Situations have however greatly improved over the past few years. Along with an increasing popularity of paediatric MIS and hence a rapid increase in market demand, there has been a substantial increase in production by the industry and supply of fine laparoscopic instruments that are tailor-designed for small infants and children. This has contributed immensely to the recent explosive development and wide application of laparoscopic surgery in various fields of paediatric surgery. We are now using small 2, 3, 5 mm instruments for most of our cases. These fine instruments allow more sophisticated laparoscopic operations to be performed safely and effectively. Also smaller instruments is linked with greater patient tolerance and less pain.<sup>4</sup> In addition, improved technology in optics, particularly with the development of the small-sized high quality Hopkins rod lens laparoscopes, also plays a very important role in the growth of laparoscopic surgery in children.<sup>5</sup> Nowadays, we commonly used fine 3-5 mm laparoscopes for nearly all of the procedures. All these, together with the better understanding of operative ergonomics, improvement in laparoscopic surgical techniques and cumulating experience, contribute to the remarkable development in paediatric laparoscopic surgery in less than a decade.

Currently, the great majority of surgical procedures in infants and young children that traditionally would require an open operation can be safely and effectively conducted using the laparoscope.<sup>1</sup> Furthermore, the advent of MIS has actually revolutionised and set the gold standard in the management of many surgical conditions in children, e.g., laparoscopic primary one-stage pull-through for Hirschsprung's disease has largely replaced the conventional multi-stage open approach, which commences with a defunctioning enterostomy.<sup>2</sup> To date, the results of paediatric laparoscopic surgery have been very encouraging. There appears to be little doubt that the era of MIS has come and this will form a main direction for development in neonatal and paediatric surgery in the new millennium. This article aims to provide an update of the current status of application of MIS for various surgical conditions in the newborns and infants.

## Laparoscopic Surgical Procedures in Newborns and Infants

Nearly all surgical procedures in infants that have been performed traditionally via an open approach have been successfully conducted laparoscopically. For some disease conditions, e.g. Hirschsprung's disease, imperforate anus, gastro-oesophageal reflux, etc. the laparoscopic approach has greatly improved the surgical outcome, and has quickly gained wide acceptance among paediatric surgeons worldwide as the treatment of choice. One should however remember that simply because a procedure is technical feasible using the laparoscopic approach does not imply that this is the best way to do so. Many factors have to be considered before a decision for or against the MIS approach can be made. These include the surgeon's operative experience in laparoscopic surgery, the competence and set-up in MIS of the respective centre or hospital, the complexity of the procedure, the patient's medical condition, the parents or the family's preference, the additional cost incurred for the laparoscopic approach compared to the open method, etc. It must also be noted that despite this era of evidence based medicine, there are as yet extremely few prospective randomised studies of laparoscopic surgery in infants, partly because of the intrinsic small number of many of the surgical conditions in this age group. Nevertheless, the field of paediatric MIS is rapidly evolving: more and more surgeons are getting well trained in laparoscopic techniques, and technology in optics and instrumentation continue to improve. Procedures that are now regarded as technically difficult and perhaps of doubtful benefits, may become feasible and straightforward and hence well accepted in the near future.

### **Primary Laparoscopic Pull-through for Hirschsprung's Disease**

Hirschsprung's disease is one of the common causes of intestinal obstruction in the neonatal period. Traditionally, it is managed by a three-stage approach, with a defunctioning stoma fashioned at the time of diagnosis, followed by the definitive pull-through operation in a few months' time and then closure of the stoma subsequently.<sup>6</sup> This has the disadvantages of requiring 3 major operations, along with their potential complications. Also, care of the enterostomy stoma is labour intensive, not to mention the additional possible complications related to the stoma such as prolapse, retraction, stenosis, bleeding, skin excoriation, etc. The advent of laparoscopic primary one-stage pull-through, without the need for a covering enterostomy stoma,

has completely revolutionised the management strategy of Hirschsprung's disease.<sup>2,7-9</sup> This avoids the need for fashioning as well as care of a stoma, multiple operations, anaesthesia and their potential complications. Once the diagnosis is made, laparoscopic primary pull-through can be performed in the great majority of cases and irrespective of age, with the only exception for patients with fulminant enterocolitis or those with ultra-long segment or total colonic aganglionosis.

Several methods have been described for the laparoscopic pull-through procedure. Initially, there were reports on the use of laparoscopic Swenson<sup>10-12</sup> and Duhamel procedures.<sup>7,9</sup> In addition, there are also sporadic reports of transanal pull-through. This latter however has severe restrictions when the extent of the disease is longer than expected.<sup>13,14</sup> Currently, it is Georgeson's modified Soave procedure that has gained the widest popularity.<sup>2,8</sup> We have been using the technique as described by Georgeson,<sup>2</sup> although we routinely used three instead of four laparoscopic ports. Infants are placed transversely across the table and the whole lower body is prepared and draped. A 30 degree 5 mm laparoscope is inserted via an umbilical port and CO<sub>2</sub> pneumoperitoneum is established at around 8-10 mmHg. A 3 mm and a 5 mm working ports are inserted into the left mid quadrant and right mid quadrant respectively. Serial seromuscular biopsy is first taken under laparoscopic guidance to delineate the extent of aganglionosis and the transition zone. The sigmoid colon and rectum are then mobilised laparoscopically under direct endoscopic vision. The dissection is kept closed to the bowel wall all the way down to about 1-2 cm below the peritoneal reflection. The operation is then switched to the perineal part and a mucosal tube is dissected circumferentially, leaving an outer seromuscular cuff, starting from just above the dentate line until it joins the lowest point of the upper dissection. The bowel is then pulled through the anal wound. Excess bowel is excised and an end-to-end colo-anal anastomosis is then made just above the dentate line.

With the availability of the laparoscope, meticulous dissection in the small pelvis of infants and newborns is feasible. It allows extremely good illumination and visualisation of the surgical field, and hence meticulous dissection that can not be achieved by open surgery. With proper training in MIS techniques, this procedure can be picked up quite readily. When compared with the open methods, earlier commencement of feeding and shorter hospital stay can be achieved. In Georgeson's initial series of 24 patients in 1998, the average length of day was about 3.5 days and early postoperative complications were minor

and infrequent.<sup>15</sup> From a more recent series of 80 cases from 5 centres using the same surgical technique, it has been shown that early return of bowel function was almost universally achieved, with most having bowel motion within the first 24 hours. Feeding could be re-established soon after surgery and the mean hospital stay was only about 3.7 days.<sup>2</sup> Major complications were infrequent and included: anastomotic leak in 2 patients (2.5%), and enterocolitis in 6 patients (7.5%) of which 3 required diversions.<sup>2</sup> The initial results therefore showed that one-stage primary laparoscopic pull-through is safe and effective in most patients, and has obvious superiority over the conventional multi-stage open approach, although larger series with longer follow-up will be necessary to address the aspect of bowel function and continence. It is also possible that better long-term bowel function may be achieved as the infant can pass faeces normally per anal soon after birth, and bowel continuity has been maintained all along without any interruption by a defunctioning stoma.

#### ***Laparoscopic-assisted Anorectal Pull-through for Imperforate Anus***

Traditionally, management of intermediate or high type of imperforate anus entails an initial defunctioning colostomy, followed by an anorectal pull-through usually via a posterior sagittal approach after a few months. In patients with high type malformations, a combined abdominal perineal approach is often required, necessitating a large laparotomy wound for mobilisation of the bowel.<sup>16</sup> Over the past few years, the laparoscopic approach has also been used for pull-through operations for both intermediate and high anorectal malformations. The laparoscope, together with the perineal muscle stimulator, allows easy localisation of the rectal fistula, clear delineation of the surgical anatomy and pelvic floor musculature, and accurate placement of the rectum through the centre of the sphincteric muscle complex via a minimally invasive approach, thus obviating the need for making a large abdominal incision.<sup>17,18</sup> The initial good results in older infants who had defunctioning colostomy encouraged the development of one-stage primary pull-through in newborns with intermediate or high anorectal malformation without the necessity of fashioning of a stoma.<sup>17</sup> This has the added benefits of sparing two other major operations and particularly the potential complications of a colostomy. Primary pull-through without a stoma may also have the potential benefit of better bowel function as bowel continuity is established immediately after birth although long-term data regarding this issue is still pending.

With improvement in paediatric MIS skills and experience we have been routinely performing one-stage pull-through in newborn infants who have intermediate or high anorectal malformations over the past two to three years. Our experience shows that the laparoscope provides an excellent illumination and visibility right down to the pelvic floor and the levator ani even in the very small pelvis of the newborns. The ano-rectal pull-through procedure starts with insertion of an urethral catheter. The newborn infants is then placed across the end of the operating table. The whole abdomen, perineum and the lower limbs are prepared and draped. Three 3-5 mm laparoscopic ports are used. Carbon dioxide pneumoperitoneum is established at 8-10 mmHg. Under direct laparoscopic vision, the rectum is mobilised distally all the way below the peritoneal reflection until it either ends blindly, or in most cases tapers off into a fistula which joins the bladder or the urethra, or occasionally the vagina in girls. The rectourinary fistula, if present, can be closed easily by intracorporeal suturing. The operation is then switch to the perineal part. The site for the neoanus is marked with the help of the electrical muscle stimulator and a small incision is then made. Under laparoscopic vision and with the guidance of electrical muscle stimulation the exact site of the sphincteric muscle complex is cleared visualised and a Veress needle with a radially expandable sheath is inserted through its centre via the perineal incision. A 10 mm port is then inserted through the expandable sheath and the mobilised rectum is then pulled through the perineal wound and ano-rectal anastomosis is then fashioned. The use of laparoscope allows very accurate and precise placement of the pull-through bowel, with the added advantage of just splitting but not cutting of the sphincteric muscle complex, as described in Pena's posterior sagittal approach.<sup>19</sup> The minimal dissection at the perineum allows safe pull-through without a protective stoma. In contrast, the conventional posterior sagittal anorectoplasty requires extensive dissection for separation of the sphincteric muscle, location of the bowel and closure of the fistula, and it would be unsafe to leave without a protective stoma. It is also technically extremely difficult to perform the posterior sagittal pull-through precisely in small neonates. On the contrary, however, the laparoscopic primary pull-through can be safely performed even in small neonates. This saves 2 operations and their potential complications. In addition, the bowel function might be superior to those with staged surgery as the continuity of bowel is established soon after birth. It is also not necessary to divide the sphincter as in the posterior sagittal approach. Preliminary results have

been very promising although long-term data is required to address the issue of faecal continence.

#### ***Laparoscopic Pyloromyotomy for Hypertrophic Pyloric Stenosis***

Since the first description of laparoscopic pyloromyotomy by Alain et al in 1991,<sup>20</sup> there have been various reports on the use of MIS technique for hypertrophic pyloric stenosis.<sup>21-23</sup> However, the laparoscopic approach has so far not gained universal acceptance as in primary laparoscopic pull-through for Hirschsprung's disease. When compared with conventional open pyloromyotomy, or Ramstedt's operation, there is no significant advantage with respect to the operative time, postoperative emesis, duration of hospitalisation and complication rate.<sup>21</sup> It has also been argued that the circum-umbilical incision employed in open pyloromyotomy carries the same good cosmetic result as with the laparoscopic approach, although it is believed that the open group might have a higher wound infection rate. In the open method, it is necessary to bring the pyloric "tumour" out through the abdominal incision for the pyloromyotomy, and the resultant tissue traction and manipulation may attribute to a delay in return of gastric function in some of the infants. These problems can be all avoided using the laparoscopic technique. Results from recent studies showed that laparoscopic pyloromyotomy is at least as safe and effective as the open Ramstedt's pyloromyotomy, which hitherto has been regarded as the gold standard. With increase in experience, one may expect that the laparoscopic method may prove to be more superior than the traditional method.

#### ***Laparoscopic Fundoplication for Gastro-oesophageal Reflux***

Laparoscopic fundoplication with or without a feeding gastrostomy has become one of the most commonly performed laparoscopic procedures in infants and young children, especially for those with neurological impairment and feeding problems.<sup>24,25</sup> Recent large series have produced convincing data that the laparoscopic method achieves significant advantages over the traditional open procedure, and is associated with a lower complication rate, more rapid recovery and a shorter hospital stay.<sup>24</sup> The average duration of stay after surgery is only about 2-3 days.<sup>24,26,27</sup> This is probably related to the much smaller sized wounds and hence less postoperative respiratory compromise. This is particularly important in the neurological impaired infants with severe gastro-oesophageal reflux disorder and poor pre-operative chest conditions. When compared with

historical control, it is also found that the intermediate and long-term results are comparable to that of open fundoplication.<sup>28</sup> Because of the encouraging results for laparoscopic fundoplication, the procedure has gained wide acceptance from most parents and paediatricians, resulting in a rapid increase in the number of referrals in recent years.

We have been routinely performing fundoplication for gastro-oesophageal reflux using the laparoscopic approach in infants and young children over the past 5-6 years, with very satisfactory results. The patients are placed in the supine position with legs separated. In those with lower limb contracture, the legs may be hanged at the end of the table. A 5 mm port is then inserted through the umbilical wound and CO<sub>2</sub> pneumoperitoneum is established at around 10-12 mmHg and a 5 mm 30 degree laparoscope is usually used. Three 3-5 mm working ports are then inserted at the upper abdomen. A liver retractor is inserted through a small epigastric incision. The oesophageal hiatus is identified and the abdominal part of the oesophagus is mobilised followed by the mobilisation of the upper part of the greater curve of the stomach. The oesophageal hiatus is then repaired and fundoplication is accomplished by a 360° Nissen wrap around the abdominal oesophagus. In those neurological impaired children with feeding problems, laparoscopic-guided gastrostomy is then fashioned through one of the port sites. Gastrostomy tube feeding can be started once the gastric ileus, which is usually minimal, is over.

#### ***Duodenal Atresia and Intestinal Atresia***

Laparoscopic duodeno-duodenostomy for duodenal obstruction in infants and young children has been reported recently, showing that the procedure, although technically demanding, is feasible in the hands of experienced paediatric laparoscopic surgeons.<sup>29</sup> However, the pre-operative condition of the infant, especially in those with Down's syndrome and severe cardiac problem, often poses a limiting factor for application of the laparoscopic approach. The surgical principle is the same in both the laparoscopic and open method. A diamond shaped duodeno-duodenostomy anastomosis is fashioned using intracorporeal suturing techniques under laparoscopic guidance. Unlike other causes of neonatal intestinal obstruction where the obstructive lesion is more distal to the duodenum, the distal small bowel in duodenal atresia is not distended, hence allowing sufficient room for surgery after the establishment of carbon dioxide pneumoperitoneum. Early results from our unit using this technique

has been encouraging, although a bigger series with more long-term follow-up data will be necessary to justify its routine application.

#### ***Malrotation***

There are only a few recent reports on the use of the MIS technique in the management of intestinal malrotation, mainly in cases without concomitant volvulus.<sup>30-32</sup> It can be employed as a useful diagnostic tool especially in cases with a strong clinical suspicion of malrotation and volvulus but with indefinite or equivocal findings on the contrast study. With the use of the laparoscope, the exact anatomy can be defined clearly through tiny incisions. If the diagnosis is confirmed, a standard Ladd's procedure can be performed, either with an open or a laparoscopic technique.<sup>31</sup> However, it is still debatable whether the laparoscopic technique is advantageous for the reduction of volvulus, particularly if significant intestinal ischaemia or even imminent bowel gangrene is already present. In the presence of hugely distended and oedematous bowel, it is difficult to achieve good pneumoperitoneum and laparoscopic derotation of the volvulus may be difficult and even dangerous.<sup>31</sup>

#### ***Oesophageal Atresia***

With the advances in laparoscopic technique and instrumentation, even the most complex reconstructive surgery such as the repair of oesophageal atresia with or without tracheo-oesophageal fistula, can now be accomplished by the laparoscopic approach.<sup>33</sup> Management of this group of newborn infants is particularly challenging as they are often premature or small for gestational age and may have severe associated congenital malformations, e.g. cardiac anomalies. The small thoracic cavity in these small infants poses special technical problems for fine movement and manipulation of the laparoscopic instruments, and meticulous endoscopic dissection and intracorporeal suturing skills are essential. Accurate and stable endoscopic vision is also crucial to success of the procedure and a computer-assisted robotic arm for optimal positioning of the endoscope often provides remarkable help.

For the procedure, it is pertinent to acquire one-lung ventilation to allow more operative space inside the small chest cavity of a newborn infant. After endotracheal intubation, an Fr 3 Fogarty catheter is passed to the right main bronchus. The patient is then placed in a semi-prone position. The first trocar is inserted in the 4th intercostal space in the posterior axillary line for the passage of a 30-degree laparoscope. Another two trocars are inserted

via the 2nd and 6th intercostals space at the mid axillary line. Carbon dioxide insufflation is set at a low pressure of about 4 mm Hg and the Forgarty balloon is then inflated to block off the right main bronchus. As in the open method, the azygos vein is divided first. By following along the vagus nerve, the distal oesophageal pouch is identified and mobilised. The tracheo-oesophageal fistula is clipped or sutured close to the trachea. The upper oesophageal pouch is then fully mobilised to the thoracic inlet. Both ends are trimmed and an end-to-end oesophageal anastomosis is fashioned by intracorporeal suturing under thoracoscopic vision, using fine monofilament interrupted sutures over a feeding tube that is passed to the stomach. A Fr 12 chest drain is then inserted and the lung is re-expanded. Oral feeding can be started on 4 to 5 days postoperatively when a barium swallow does not show any leakage.

The minimally invasive thoracoscopic technique obviates the need for a big and painful open thoracotomy that may potentially lead to future musculoskeletal problems, resulting in scoliosis and shoulder girdle weakness. The small port sites for the thoracoscopic procedure remarkably minimise the severe wound pain that is a hallmark after an open thoracotomy, and significantly reduces the need for post-operative ventilatory support and chest complications. In addition, with optical magnification by the laparoscope, the oesophageal anastomosis can be fashioned very accurately and meticulously, and assuring good apposition and incorporation of the mucosa in the anastomosis. Preliminary data from published series and from our unit show that this procedure can be safely performed with satisfactory results in experienced hands.

### ***Intussusception***

Intussusception is one the common causes of intestinal obstruction in infancy. Pneumatic or the hydrostatic reduction has been the method of choice and carries a high success rate. Nevertheless, there are still about 10-20% of cases that the non-operative reduction is not successful. Traditionally, this requires laparotomy via a large right-sided abdominal wound. Nowadays we may try to use the laparoscope to reduce the intussusception. This is particularly useful in those the obstruction is not too tight and in those with doubtful complete reduction after air enema.<sup>34-36</sup> For those with severe obstruction or gangrenous bowel, it is no doubt that the laparoscope can't serve the purpose and we still need to proceed to formal laparotomy.<sup>34</sup> However, the laparoscope at least

can save a certain proportion of patients from laparotomy and also used as a good diagnostic tool in those with doubtful complete reduction. It may also help to locate pathological lead points such as Meckel's diverticulum in some patients. In the past few years, we have routinely used the laparoscope for those who have failed pneumatic reduction. In about half of the cases, formal laparotomy was spared.<sup>35,36</sup> More rapid recovery was observed in the laparoscopic group, probably related to less bowel exposure and manipulation.

### ***Inguinal Hernia***

Inguinal herniotomy is one of the most common operations performed in infants. Yet there are still lots of controversies in its management. One of these is the debate on the management of a possible coexisting contralateral patent processus vaginalis, which occurs in about 20-30% of cases. Various workers have previously advocated either routine contralateral inguinal exploration, or routine inspection of the peritoneal cavity with a laparoscope inserted through the opened ipsilateral hernial sac for a contralateral hernia.<sup>37,38</sup> In the presence of a patent processus vaginalis, contralateral open exploration is then carried out. However, this method can be technically difficult in some cases. It may not be possible to insert the laparoscope through a small and thin hernial sac and there may be peritoneal folds overlying the contralateral inguinal orifice, and thus obscuring for any possible underlying hernia. To solve these problems, trans-umbilical laparoscopic herniotomy has been reported in recent years.<sup>39-41</sup> In this method, the deep ring is closed by the laparoscopic suturing technique. The initial result shows that this may be a good alternative with satisfactory success rate. The distinct advantage over conventional open herniotomy is that the possibility for a subsequent contralateral hernia, and hence the risk for another hospital admission, general anaesthesia and operation is avoided. A recurrence rate of about 3-4% was recently reported from a large series of 933 repairs in 666 children.<sup>41</sup>

We have developed a novel method of inguinal hernial repair. Through an umbilical port CO<sub>2</sub> pneumoperitoneum is established at 10-12 mmHg. A 3 mm grasper is then inserted through the abdominal wall over the suprapubic region to facilitate dissection of the hernial sac. A specially designed herniotomy hook carrying a suture is then passed through a small 2 mm stabbed incision over the internal inguinal ring. This is used to dissect the hernia sac circumferentially,

separating the sac from the vas and testicular vessels in boys, and carrying the suture circumferentially around the hernial sac. The sac is then ligated and closed. In the presence of a contralateral sac, another small 2 mm stabbed incision is made over the contralateral deep ring and the sac is then closed in a similar fashion. Only the umbilical wound needs suture closure while the other small wounds are just taped with steristrips. Over the past 3 years, we have performed laparoscopic herniotomy in over 200 infants and young children with the method described above. There were no intraoperative complications encountered, and no open conversion was required. With a mean follow-up of 12.5 months, there were only 2 recurrences (1.8%). There was no reactive hydrocele or testicular problem. This is comparable to the results of open herniotomy although data on long-term results is still pending.

#### ***Laparoscopy for Hepatobiliary Pathologies in Infants***

The laparoscope is a very useful investigation in assessing neonates with prolonged jaundice. When combined with laparoscopic-guided intra-operative cholangiogram, it is a very sensitive and specific tool in diagnosing or excluding biliary atresia.<sup>42</sup> If the diagnosis is not apparent after the conventional blood tests and radiological imaging such as ultrasound and EHIDA scan, it is our practice to proceed to laparoscopy and intra-operative cholangiogram, and proceeding to a laparoscopic Kasai's portoenterostomy if biliary atresia is confirmed under the same setting. With this approach, very valuable time before the critical limit of 10-12 weeks of age for a good result will not be wasted in other investigations such as liver biopsy, ERCP, etc. Early surgery can be contemplated in patients with biliary atresia to secure a better outcome. For other conditions causing persistent neonatal jaundice, laparoscopic-guided liver biopsy can also be performed. With increasing experience in various laparoscopic procedures in newborns and infants, we have found it completely safe and effective to perform complicated hepatobiliary reconstructive surgery in young infants laparoscopically. These include excision of choledochal cyst with hepatico-jejunostomy, Kasai's portoenterostomy for biliary atresia, and subtotal pancreatectomy for infants with nesidioblastosis and persistent hyperinsulinaemia after failed medical therapy.

Although there have not been reports in the literature, we have found that the Kasai's portoenterostomy procedure can be effectively and safely performed

laparoscopically in young infants with biliary atresia. Under endoscopic vision the fibrous cord is meticulously dissected from the portal vein, hepatic artery and the adjacent structures in the porta hepatis. The base of the fibrous cone is then transected at the level of the posterior wall of the portal vein bifurcation, exactly similar to that in an open Kasai operation. A loop of proximal jejunum is then identified laparoscopically and brought to the abdominal surface via the umbilical port site. A 40 cm jejunal Roux loop is then fashioned. The bowel is then returned to the abdominal cavity and carbon dioxide pneumoperitoneum re-established. A Kasai's type of portoenterostomy is then fashioned laparoscopically with fine 6-zero monofilament sutures. Once again the small operative space in the porta hepatis in these small infants can pose substantial technical difficulties for fine control and manipulation of the laparoscopic instruments, and careful endoscopic dissection and good intracorporeal suturing skills are essential. Accurate endoscopic vision is also important to facilitate the procedure and a computer-assisted robotic arm for optimal positioning of the endoscope has been found to be of profound help. Over the past two years we have successfully performed laparoscopic Kasai's portoenterostomy in six infants. The learning curve has been very steep, with the first case taking just over 6 hours, but the operating time decreased dramatically to only around 4 hours in the last 2 cases. Jaundice was completely cleared in 4 patients while the serum bilirubin level was also on downward trend for the last patient. One patient had remained jaundiced after surgery and had undergone a liver transplant 9 months later. Blood loss was minimal in each case and there were no major complications in this series. We have found that with the laparoscopic approach one can obtain an extremely clear and magnified view of the portal structures. Bowel exposure to surgical manipulation by the surgeons' hands is avoided and hence postoperative ileus can be minimised. Early return of bowel function was observed in all our patients and feeding could be started earlier. This method also has the potential benefit of less adhesion and this could make a future liver transplantation much easier.

There are sporadic reports on the use of a MIS approach for excision of choledochal cyst and reconstruction with hepatico-jejunostomy in a few adults but there similar reports in children have not yet been available.<sup>43,44</sup> Up to this moment we had successfully performed laparoscopic excision of type I choledochal cyst and reconstruction with hepatico-jejunostomy in 12

children, ranging from 1 to 16 years old with a mean age of 5.2 years. We had used the similar approach as in a laparoscopic Kasai operation. The choledochal cyst was initially excised laparoscopically, followed by the fashioning of the jejunal Roux loop extracorporeally, and then laparoscopic reconstruction with hepatico-jejunosomy. Once again the learning curve for the procedure was steep and for the last few cases, the whole procedure took just barely over 4 hours, which was totally comparable to an open method. More rapid return of bowel function and post-operative recovery in general was observed in the majority of cases. There were no major complications in all these patients. Our initial results show that laparoscopic excision of choledochal cyst and reconstruction is feasible and safe even in small infants, and has the potential benefits of more rapid recovery and much better cosmetic result.

#### **Safety of Laparoscopic Surgery in Children**

The scope of laparoscopic surgery in children is ever expanding. It is now applicable for even very complicated reconstructive procedures in young infants, such as oesophageal anastomosis, excision of choledochal cyst and Kasai operation, and has achieved comparable results to open surgery. Yet at present we still await data from larger series and more long-term results, before we can conclusively decide which is a better method. Currently there are data from large series coming from some well-established centres in paediatric MIS, confirming the safety and effectiveness of laparoscopic surgery even in small neonates. The overall complication rate was around 1% to 4%.<sup>1,45-47</sup> In Rothenberg's series on 195 laparoscopic procedures on 183 infants weighing 1.3 to 5.0 kg, there were only 2 open conversions, 2 intra-operative complications, and no mortality.<sup>45</sup> Complications were mainly related to technical errors during the early part of the series when experience in laparoscopic surgery was less well developed. The incidence of technical complications usually dropped dramatically with increasing experience in laparoscopic surgery. There was no mortality reported in these large series including thousands of patients with laparoscopic surgery performed over the past decade.<sup>1,45-47</sup> The employment of open Hasson method for the insertion of the laparoscope has largely ameliorated complications related to Veress needle and blind insertion of the first trocar.<sup>47,48</sup> With proper training and increase in experience, laparoscopic surgery can be safely performed in young infants and even small neonates with minimal morbidity and mortality.

#### **Conclusion**

Laparoscopic surgery in children certainly carries many advantages. These include less pain, more rapid recovery, shorter hospital stay, less wound complications and better cosmesis. The laparoscopic technique has also revolutionised the management of some disease conditions in children such as Hirschsprung's disease, imperforate anus, and gastro-oesophageal reflux. Although at present data from large prospective series on safety and efficacy of the laparoscopic technique in young infants are still lacking, preliminary data provides convincing evidences that the technique is very promising. With increase in experience, rapid advancement in technology and better understanding of the physiological impact of the procedure, what is difficult to accomplish today may become a straightforward routine in the near future, and it is almost certain that laparoscopic surgery in infants and young children will become more widely accepted.

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