Review

Laparoscopic surgery in children

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A review of laparoscopy as used in paediatric surgery with special reference to cholecystectomy, appendicectomy, fundoplication, the undescended testicle, inguinal hernia and hydroceles.

Key words: Laparoscopy – Paediatric surgery

The operative repair of an oesophageal atresia has been regarded as the epitome of the paediatric surgeon's art. The first successful ligation of the distal fistula and end-to-end oesophageal anastomosis was performed in the US by Cameron Haight in 1948.¹ In 1999, Lobe *et al.*² reported the first repair performed entirely thoracoscopically, and in 2002 the first series of 8 infants was reported from The Netherlands.³ If such a 'technical' operation can be accomplished in a 2–3 kg newborn infant, what is the future of open surgery for paediatric surgeons?

Laparoscopy specifically, and minimally invasive surgery generally, have changed surgical practice and training irrevocably. Techniques, once confined to gynaecologists and perhaps only the most committed of adult general surgeons, are now all pervasive. Although driven perhaps by technology and the manufacturers of surgical instruments, it has certainly been sustained by patient expectation. While the ambition of enthusiasts appears unlimited with most open surgical techniques on the gastrointestinal tract having been attempted laparoscopically, the majority of procedures are still open rather than closed. Certainly in adults, laparoscopic cholecystectomy seems unquestionably superior to traditional open cholecystectomy (if not mini- or small incision cholecystectomy⁴) in terms of cosmesis, analgesic requirements, respiratory-associated morbidity, a

shorter hospital-stay and also it seems from the patient's viewpoint.⁵ The initial worries over the increased risk of serious bile duct injury appear to have been passed over as a 'learning experience'. The pendulum of surgical acceptance has swung back towards open procedures in other areas. Thus, the role of laparoscopic hernia repair is less clear. A recent meta-analysis of randomised trials of inguinal hernia repair in adults⁶ suggesting that only earlier return to work and perhaps a reduced need for postoperative analgesia was in favour of the laparoscopic repair groups as against a higher incidence of potentially severe vascular or visceral injuries. Initial enthusiasm has been muted and the demand appears to have ebbed, possibly because advocates of open repairs have responded by performing many more as day-cases under local anaesthesia that negates some of the perceived advantages of a minimally invasive approach.

How has this paradigm affected the surgery of children? Paediatric surgery remains the smallest branch of surgery within the UK with less than 100 consultants having a gastrointestinal or intra-abdominal interest.⁷ What procedures are best done by occasional laparoscopists and what are better left to the pioneers. The potential for minimally invasive surgery is certainly there and in this respect European centres lead the way. For instance, in one study in a children's hospital in The Netherlands, 60% of all intra-abdominal operations were

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performed laparoscopically.⁸ Nothing comparable has thus far been reported from the UK.

The aim of this review was to subject the reported literature to critical analysis, identifying those procedures where a definite benefit could be shown and those where the benefit appeared to be less for the patient than for the operator's ego. I limited it to those conditions obviously within the abdominal cavity (*e.g.* cholecystectomy, fundoplication) and those more within the province of the 'general' surgeon (adult or paediatric) rather than the committed urologist (*e.g.* impalpable testis surgery rather than nephrectomy). The history of the development of paediatric surgery has been one of empiricism and individualism and the term 'evidence-based medicine' is an aspiration rather than a requirement in this specialty. In the paediatric surgical literature, less than 0.5% of published papers concern randomised controlled trials. In terms of the levels of evidence, most of the following studies are, therefore, at level 3 (well-designed, non-experimental descriptive studies).

Laparoscopic cholecystectomy

First performed in adults by Dubois *et al.*⁹ and Reddick and Olsen in 1989,¹⁰ laparoscopic cholecystectomy (LC) has become the standard bearer for minimally invasive general surgery. Currently, as well as cholecystectomy, it is possible to offer laparoscopic exploration of the common bile duct and removal of stones¹¹ and, in a proportion of cases, management as a day-case.¹²

Gallstones in children are uncommon but not exceptional. Most arise in children with an underlying haemolytic disorder such as spherocytosis, elliptocytosis and stomatocytosis and the more prevalent, thalassaemia (α and β), haemoglobin C and sickle cell disease (SCD). Cholesterol stones can be seen, particularly in overweight adolescent girls; one ultrasound screening programme performed in children between 6–15 years of age showed a prevalence of 0.13%.¹³ For comparison, the prevalence among screened adults would be about 10%.

Typically, four ports will be used in paediatric practice (as in adults) – umbilical, epigastric and two lateral ports placed in the right lower quadrant in smaller children or in the flank in the older child or adolescent. Although all these ports can be 5 mm in diameter, a 10-mm port through the umbilicus facilitates final removal of the gallbladder. Initial port placement in children and certainly infants should now always be by an open or Hasson approach as opposed to use of a guarded Veress needle.

There have been no randomised studies comparing open and LC in children. The initial series were simply observational in small groups of patients^{14–17} or small groups compared with historical controls.^{18–20} More

recently, series of more than 100 children have been reported^{21,22} albeit often from combined centres. All series show that LC is safe with a low risk of complications and probably reduces hospital stay. Common bile duct injury has not been described as a problem, possibly because of small numbers.

Are there any physiological benefits from LC in the paediatric population most at risk – children with sickle cell disease? Wales *et al.*²³ reported a retrospective study that examined the incidence of the acute chest syndrome following surgery in children with sickle cell disease. This is a potentially serious complication of sickle cell disease characterised by erythrocyte sickling within the pulmonary vasculature. Though there was an increased incidence in intra-abdominal surgical procedures (20%) compared to extracavitary procedures, no difference was observed whether the procedure was open or laparoscopic. Jawad *et al.*²⁰ compared open ($n = 7$) and laparoscopic cholecystectomy ($n = 11$) and found reduced postoperative analgesic requirement and a reduced hospital stay in the latter group.

There are still debates over the role of operative cholangiography, which is technically difficult in children and the timing of intervention when choledocholithiasis is suspected. For instance Newman *et al.*²¹ described pre-operative ERCPs in 14 adolescents with imaging suggestive of common duct stones followed by LC some 4 days later. At follow-up, no retained stones were identified and all had an uncomplicated recovery. Certainly ERCP rather than laparoscopic exploration seems to be the recommended option.

Laparoscopic appendicectomy

Appendicectomy is the commonest intra-abdominal operation in the UK. Every surgical trainee (and probably their patient) will remember their first solo appendicectomy. Although perhaps the incidence of this rite of passage has declined over the past decades, it does remain an operation within the scope of most basic surgical trainees. However, the same could probably not be said for its laparoscopic removal. How frequently laparoscopic appendicectomy (LA) is being performed in children in the UK is not known, and indeed demographic data in other countries are similarly scarce. For example, an analysis of all appendicectomies in the state of Missouri, USA in children from 6–15 years old, during 1997 showed that 22% were removed laparoscopically.²⁴

There are four recent large published comparative series of laparoscopic appendicectomy in children with their data summarised in Table 1.^{25–28} All are largely observational and not subject to the rigours of a prospective randomised trial. There are four smaller-scale randomised trials in 43 children from Finland,²⁹ 63 children from

Table 1 Laparoscopic appendicectomy in children – comparative institutional series

Reference	Number		Structure	Summary of results
	LA	Open		
Paya ²⁵	138	362	NR	Higher risk of major complications in open group (3% versus 0%)
Canty ²⁶	955	173	NR	Longer operating times in perforated appendicitis (68 versus 58 min) Comparable hospital stay (2 versus 3 days) No difference in abscess rate, or wound infection (1% versus 0.4%)
Lavonius <i>et al.</i> ²⁹	23	20	Randomised	No differences in hospital stay, analgesia or complications
Krisher <i>et al.</i> ²⁷	140	302	NR, historical controls	High incidence of intrabdominal abscess (24% versus 4.2%) in perforated appendicitis
Lejus ³⁰	30	33	Randomised	No difference in analgesic requirements, incidence of vomiting, <i>etc.</i>
Meguerditchian ²⁸	126	262	NR	Comparable complications (10.3% versus 8.2%), shorter hospital stay (2.3 versus 2.9 days)
Little ³¹	44	44	Randomised	No difference in analgesic used, hospital stay or complications
Lintula ³²	31	30	Randomised	Less pain Reduced length of stay (1.9 versus 2.6 days)

LA, laparoscopic appendicectomy; NR, non-randomised.

France,³⁰ 88 children from the US,³¹ and 61 children from Finland³² also summarised in Table 1. There are no reported series of paediatric LA from the UK. All series show that LA can be performed effectively and safely in comparison to the open alternative, although there are some caveats. The largest published experience remains that of El Ghoneimi *et al.*³³ from four centres in France reporting 1379 cases with a conversion rate of 0.6% and a 'white' appendicectomy rate of 10%. Overall, most authors suggest shorter hospitalisation^{26,31,32} and earlier return to normal activities although some of the controls are historical and some reports exclude the more complicated cases from LA. Average operating times vary from about 70 min in older studies³⁴ to about 40 min in the more recent.²⁶ There was no difference in visual analogue scored postoperative pain or in narcotic use between open and LA in three trials where this was reported.^{29–31} However, Lintula³² reported that pain was significantly reduced at all points with less need for rescue analgesia in their LA group.

There has been a published *Cochrane Review*³⁵ of open versus laparoscopic appendicectomy (LA) in adults with some of their conclusions applicable to the paediatric population. The results of this review suggested that wound infections were twice as likely in the open group but, conversely, there was a 3-fold increase in the incidence of intra-abdominal abscesses in those having LA. There is some evidence of this in children too. Krisher *et al.*²⁷ compared the results of LA in children to a historical cohort of open operations and identified a higher rate of intra-abdominal abscesses (6.4% versus 3%) in the former, which remained significant even when

controlled for antibiotic use, age, *etc.* Indeed if the subset of perforated appendicitis was analysed, some 27% of the LA group were complicated by abscess formation. However, no such difference has been found in other large, observational studies.^{26,28}

LA is typically performed using 3 (or 4) ports, one 10-mm umbilical port for the videoscope and for extraction and 2 (or 3), 5-mm working ports placed in the right upper quadrant and suprapubic (or left iliac fossa if small child). Three methods of amputating the appendix have been described in children: stapling (using the EndoGIA, *Ethicon Endosurgery*), ligation (using an endoloop) or laparoscopic-assisted extracorporeal appendicectomy (through the umbilical wound). The first two options were better in terms of incidence of complications compared to the latter in one paediatric trial³⁶ but not another.²⁸ The appendix is removed transumbilically, with or without the use of an endoscopic bag to protect the wound from direct soiling. Drains may be left if they are believed useful.

Laparoscopic fundoplication

Gastro-oesophageal reflux (GOR) disease is common during infancy, responds well to symptomatic treatment, and in the majority diminishes with increasing age. A small proportion of otherwise normal children may develop GOR-induced stricture, oesophageal bleeding, recurrent aspiration, *etc.* and will have intractable symptoms requiring consideration of more invasive therapy. However, the group which does require surgical therapy for control of GOR and vomiting are those who are described as neurologically impaired, due to cerebral

palsy, Down's syndrome, metabolic diseases, *etc.* GOR in these children can make life for the child and carers miserable with constant reflux, regurgitation, aspiration and coughing.

Collins *et al.*³⁷ compared a series of paediatric LN with a historical open group and found a shorter hospital stay (6 versus 10 days), but no difference in incidence of complications or morbidity. Allal *et al.*³⁸ described a large series of 142 children from France of laparoscopic fundoplications, with a mean age of 5.5 years. Conversion was necessary in only three cases and a variety of anti-reflux techniques were performed including a Nissen (360°) wrap ($n = 83$) and a Toupet (180° anterior) wrap ($n = 56$). A marked learning curve was experienced with all the conversions and complications ($n = 4$) occurring in the first 60 cases. The largest published personal experience is from Rothenberg in Denver, USA who has reported 220 consecutive LN procedures.³⁹ Only two (0.9%) were converted and there were three complications (two perforations and one pneumothorax. Recurrent herniation occurred in 7 (3.2%) children, which is exceptional compared even to some series of open fundoplications.⁴⁰ Table 2 illustrates recent experience with LN.

LF in children is performed typically using five ports (two 5-mm working ports, one 5-mm liver retractor, one 5-mm stomach grasper and one 10 or 7 mm camera port) with the surgeon standing between the child's legs. Smaller (3–4 mm) ports have been described for use in infants. The short gastric vessels may or may not be ligated although some authors regard this as crucial to success.³⁷ The procedure involves peri-oesophageal dissection, restoration of a crural hiatus, creation of an oesophago-gastric window followed by placement of a tension-free fundal wrap. The wrap can be sutured or clipped. Endoscopic insertion of a gastrostomy tube and calibration of the oesophageal lumen can be added at the end.

It is tempting to suggest that LN is preferable because, at least in the UK, it is usually offered to children with many other medical problems and might offer advantages in terms of analgesic requirements, morbidity and hospital stay. However, such comparative studies have not been performed in children. The indications for fundoplication, laparoscopic or open, in the larger American series would probably be regarded as somewhat questionable in the UK.

Nevertheless, published series by those experts do show excellent results in terms of the lack of complications and preservation of wrap integrity, certainly in the short-term.

Laparoscopy for the undescended testicle

The undescended testis is a very common condition in paediatric practice, estimated to occur in up to 3–6% of boys. For the purposes of management, they can be simply divided into those that can be felt (*i.e.* are outside of the inguinal canal and somewhat towards the scrotum) and those that cannot (either because they are intra-abdominal in position or because they are absent). Although a conventional open orchidopexy is required for the former condition, there is a debated role for laparoscopy in the management of the latter – the impalpable testis. This role can be further divided based on whether its primary role is diagnostic or therapeutic. Single-port (5 mm) laparoscopy is extremely accurate in locating and assessing the quality of the intra-abdominal testis and, perhaps more importantly, establishing accurately when it is not there. It is certainly more accurate in the pre-pubertal boy than non-invasive tests such as ultrasonography, CT or MR imaging. Siemer *et al.*⁴¹ compared the accuracy of MR scanning and laparoscopy in a series of 29 boys with unilateral non-palpable testes. MR scans failed to identify testes in 12 who were then subject to laparoscopy, which actually identified a further 8 testes. Still, some surgeons argue that it offers no advantage to a conventional open exploration of the canal and adjacent area. In practice, however, the published literature suggests that there is still a significant incidence of intra-abdominal testes missed at apparently competent open surgery. For instance, Lakhoo *et al.*⁴² were able to report the findings of secondary laparoscopy in 18 boys (22 impalpable testes) with previously negative open explorations. They found that there were 13 (59%) missed intra-abdominal testes and 9 that were definitely absent due to visualisation of confluent blind-ending vas and vessels.

The correct treatment of an intra-abdominal testis is controversial. Many surgeons still take a nihilistic approach, advising removal however normal the testis appears because of its relationship with later malignancy and the unquestionably poor long-term functional (oligospermia) results of those subject to whatever form of

Table 2 Representative series of fundoplications in children

Author	Number	Wrap failure rate (%)	Mean time to discharge (days)	Percentage in neurologically abnormal children
Collins <i>et al.</i> ³⁷	60 (open)	4	10.7	53
	60 (LN)	0	6.8	53
Rothenberg ³⁹	218	3.4	1.6	12
Allal ³⁸	142	12	3	32

LN, laparoscopic Nissen fundoplication.

orchidopexy. Alternatively, and certainly in those with bilateral intra-abdominal testes, other, more constructive, techniques are available to achieve a scrotal testicular position. Almost, but not all, will involve some variant of the Fowler-Stephens' manoeuvre whereby the testicular vessels are sacrificed as a first stage prior to later mobilisation solely on the vas and vasal vessels.^{43,44}

Lindgren *et al.*⁴⁵ reported a retrospective series of 126 impalpable testes in 108 boys, of which 51 (40%) were intra-abdominal. Of these, 18 were treated principally laparoscopically either as a one-stage ($n = 13$) or a two-stage procedure ($n = 5$). Counterintuitively, and against the experience for the open alternatives, the single stage procedure was entirely successful in all cases, while in the staged group two testes atrophied. Clark and Borzi⁴⁶ also reported excellent results following laparoscopic localisation and Fowler-Stephens' orchidopexy in 26 children with 33 intra-abdominal testes. All testes were noted to be scrotal in position at follow-up, although four were indeed smaller.

Esposito *et al.*⁴⁷ suggested that because of better visualisation of inguinal and retroperitoneal anatomy obtainable at laparoscopy, it is possible to avoid division of the testicular vessels and still bring the testis to a scrotal position even in the high position. They reported a series of 70 boys with 72 impalpable testes who were subject to laparoscopy; of these, 20 intra-abdominal testes were mobilised successfully without vessel division, most being brought through the posterior wall of the canal medial to the epigastric vessels.

Laparoscopy for inguinal hernia and hydroceles

There has been much less of an impact on surgical practice in this area in children than in adults. There are fewer proponents and the perceived advantages less distinct. This is simply because an open herniotomy or ligation of a patent processus vaginalis in a child is relatively straightforward, almost invariably a day-case procedure with good long-term results and excellent cosmesis from a skin-crease groin incision often no more than 1 cm in length. So how can it be improved?

Laparoscopic repair is certainly feasible and in contrast to all of the above examples of laparoscopic surgery the technique is markedly different between adult and paediatric practice. Virtually all proponents of laparoscopic repair in children simply repair the internal ring, no more and no less; compared to the myriad of mesh-type repairs (sutured, stapled or plugged), both intra- and extra-peritoneal that has been advocated in adult practice.

The relative simplicity of the procedure and the typically smaller patient allows the use of smaller, so-called 'needlescopic', ports (2–3 mm) and sutures that are passed directly through the abdominal wall. Thus, Shalaby and

Desoky⁴⁸ reported successful needlescopic repair in 150 children with a mean age of about 5 years. The largest reported series⁴⁹ is from three of the European pioneers of this method involving 933 children. Their recurrence rate was 3.4% overall with a median follow-up of about 40 months. All ages were treated including neonates. There were no complications.

How can the laparoscopic approach be better than an open approach? Probably not in straightforward unilateral cases, but it may offer some benefits in bilateral and recurrent cases.⁵⁰

Physiological response to laparoscopic procedures in children

The anaesthetist, in particular, should be aware of certain differences in paediatric compared with adult practice. The CO₂ pneumoperitoneum typically used should be limited to about 10–12 mmHg in older children and 5–10 mmHg in toddlers and infants. Hypercarbia is frequently seen requiring an increase in inspired minute volume to compensate. Rowney *et al.*⁵¹ reported the anaesthetic aspects of 51 cases of laparoscopic fundoplication and found a median increase in PCO₂ of 7.6 mmHg, with a median duration of anaesthesia of 120 min. Gentilli *et al.*⁵² looked at the cardiac response to peritoneal insufflation in children using on-table echocardiography and found significant increases in left ventricular end-diastolic volume and end-systolic volume, although ejection fraction was preserved. Blood pressure, heart rate and mean and peak airway pressures also increased.

Some authors have described gas-less laparoscopic procedures using devices designed to 'tent' the abdominal wall and this may be particularly useful in very small children and infants.⁵³ Other problems related to the pneumoperitoneum include heat loss in the small child and the lack of control over the typical insufflator as its minimum setting is about 1 l/min, which can be too great for the smaller child.

The metabolic response to laparoscopy may not be that much different in children. For instance, Bozkurt *et al.*⁵⁴ compared 29 children with acute abdominal pain, half of whom were subjected to laparoscopy. There were no differences in insulin, cortisol, prolactin, adrenaline, lactate and blood glucose levels all of which rose during surgery of whatever type.

Finally, the cost effectiveness of laparoscopic procedures in paediatric practice have been evaluated in a few studies. In one American study, Luks *et al.*⁵⁵ identified excess operating costs of about US\$440 for each laparoscopic appendicectomy and US\$634 for a laparoscopic fundoplication. Nevertheless, there was a diminution in hospital-stay associated costs in the laparoscopy groups,

Table 3 Indications for laparoscopic intervention in children

	Pros	Cons	Notes
Appendicectomy	Common (implications for training); refines diagnosis	Instruments can be expensive	Usually unscheduled (implications for specialist surgeon and theatre staff)
Cholecystectomy	Improved recovery time; shorter hospital stay; better cosmesis	Difficult to combine with cholangiography	Unquestioned choice in adults
Inguinal hernia	Unclear	Unclear	Different procedure to adult repairs
Fundoplication	Shorter hospital stay (unproven); better cosmesis	Technically demanding	
Impalpables testes: <i>diagnosis</i>	Unrivalled examination of inguinal and retroperitoneal areas		
Impalpable testes: <i>therapeutic</i>	Easy division of testicular vessels	Mobilisation of testis more difficult than open	

equivalent to about US\$2369 and US\$5390, respectively, due to a significantly shorter stay. For instance, the mean stay for an open fundoplication was 9.8 ± 4.5 days versus 5 ± 2.8 days in the laparoscopic group ($P < 0.01$). Blewitt *et al.*⁵⁶ also compared the costs of laparoscopic fundoplication versus the open procedure in an American hospital and found that these were not statistically different; if anything, costs were higher in the open group due to a increased use of intensive care. Their mean length of stay was 2.4 days versus 4 days, respectively.

Specialist training in paediatric surgery in the UK is up to 6-years long. Within that, there is a requirement simply to be 'involved' with 20 laparoscopic procedures (diagnostic or therapeutic), which seems somewhat inadequate, with further exposure being left entirely to the trainee. Without question, laparoscopic procedures, both diagnostic and therapeutic, are here to stay in children's surgery (Table 3). Most paediatric surgeons in the UK now work within a team comprising 4–6 consultants in large regional children's hospitals. While an increasing proportion of core techniques in laparoscopy may devolve upon one member of the team who may act as a focus for the more complex procedures, it is important that laparoscopic experience and skills become established within the whole team, trainees included. Laparoscopic cholecystectomy is a superior technique, to its open counterpart; direct visualisation of the impalpable testis is unquestionably better than the alternative of inguinal exploration and laparoscopic fundoplication may offer some physiological benefits (yet to be proved), particularly in the neurologically damaged child. Laparoscopic appendicectomy is unlikely to supplant the open alternative, not least because it is usually performed as an emergency, unplanned procedure and because of doubts about its role in complicated appendicitis. Nevertheless, in some European and North American centres, laparoscopic appendicectomy is now regarded as the 'gold standard'

operation. Moreover, although not specifically reviewed, diagnostic laparoscopy should always be considered especially for atypical right iliac fossa abdominal pain in the adolescent female. Such techniques should remain part of the compendium of skills for all paediatric or general surgeons responsible for such patients and their training should reflect this.

References

1. Haight C. Congenital atresia of the esophagus with tracheo-esophageal fistula. Reconstruction of esophageal continuity by primary anastomosis. *Trans Am Surg Assoc* 1944; **62**: 623–55.
2. Lobe TE, Rothenberg SS, Waldschmidt J *et al.* Thoracoscopic repair of esophageal atresia in an infant. A surgical first. *Pediatr Endosurg Innov Techn* 1999; **3**: 141–8.
3. Bax KMA, van der Zee DC. Feasibility of thoracoscopic repair of esophageal atresia with distal fistula. *J Pediatr Surg* 2002; **37**: 192–6.
4. Majeed AW, Troy G, Nicholl JP *et al.* Randomised, prospective single-blind comparison of laparoscopic versus small-incision cholecystectomy. *Lancet* 1996; **347**: 989–94.
5. Cuschieri A, Dubois F, Mouiel J *et al.* The European experience with laparoscopic cholecystectomy. *Am J Surg* 1991; **161**: 385–7.
6. EU Hernia Trialists Collaboration. Laparoscopic compared with open methods of groin hernia repair: systematic review of randomized controlled trials. *Br J Surg* 2001; **88**: 860–7.
7. Davenport M, Howard ER. Paediatric surgical manpower in the 1990s. *Ann R Coll Surg Engl (Suppl)* 1996; **78**: 66–9.
8. Ure MB, Bax NM, van der Zee DC. Laparoscopy in infants and children: a prospective study on feasibility and the impact on routine surgery. *J Pediatr Surg* 2000; **35**: 1170–3.
9. Dubois F, Icard F, Berthelot G *et al.* Coelioscopic cholecystectomy. Preliminary report of 36 cases. *Ann Surg* 1990; **211**: 60–2.
10. Reddick EJ, Olsen DO. Laparoscopic laser cholecystectomy. A comparison with minlap cholecystectomy. *Surg Endosc* 1989; **3**: 131–3.
11. Lauter DM, Froines EJ. Laparoscopic common duct exploration in the management of choledocholithiasis. *Am J Surg* 2000; **179**: 372–4.
12. Hollington P, Toogood GJ, Padbury RT. A prospective randomized trial of day-stay only versus overnight-stay laparoscopic cholecystectomy. *Aust N Z J Surg* 200; **69**: 841–3.

13. Palasciano G, Portincasa P, Vinciguerra V *et al.* Gallstone prevalence and gallbladder volume in children and adolescents: an epidemiological ultrasonographic survey and relationship to body mass index. *Am J Gastrol* 1989; **84**: 1374–82.
14. Newman KD, Marmon LM, Attorri R, Evans S. Laparoscopic cholecystectomy in pediatric patients. *J Pediatr Surg* 1991; **26**: 1184–5.
15. Holcomb GW, Olsen DO, Sharp KW. Laparoscopic cholecystectomy in the pediatric patient. *J Pediatr Surg* 1991; **26**: 1186–90.
16. Sigman HH, Laberge JM, Croitoru D *et al.* Laparoscopic cholecystectomy: a treatment option for gallbladder disease in children. *J Pediatr Surg* 1991; **26**: 1181–3.
17. Moir CR, Donohue JH, van Heerden JA. Laparoscopic cholecystectomy in children: initial experience and recommendations. *J Pediatr Surg* 1992; **27**: 1066–70.
18. Kim PCW, Wesson D, Superina R *et al.* Laparoscopic cholecystectomy versus open cholecystectomy in children: which is better? *J Pediatr Surg* 1995; **30**: 971–3.
19. Al-Salem AH, Qaisaruddin S, Al-Abkari H *et al.* Laparoscopic versus open cholecystectomy in children. *Pediatr Surg Int* 1997; **12**: 587–90.
20. Jawad AJ, Kurban K, el-Bakry *et al.* Laparoscopic cholecystectomy for cholelithiasis during infancy and childhood: cost analysis and review of current indications. *World J Surg* 1998; **22**: 69–73.
21. Newman KD, Powell DM, Holcomb III GW *et al.* The management of choledocholithiasis in children in the era of laparoscopic cholecystectomy. *J Pediatr Surg* 1997; **32**: 1116–9.
22. Esposito C, Gonzalez Sabin MA, Corcione F *et al.* Results and complications of laparoscopic cholecystectomy in childhood. *Surg Endosc* 2001; **15**: 890–2.
23. Wales PW, Carver E, Crawford MW, Kim PC. Acute chest syndrome after abdominal surgery in children: is a laparoscopic approach better? *J Pediatr Surg* 2001; **36**: 718–21.
24. Kokoska ER, Murayam KM, Silen ML *et al.* A state-wide evaluation of appendectomy in children. *Am J Surg* 1999; **178**: 537–40.
25. Paya K, Fakhari M, Rauhofer U *et al.* Open versus laparoscopic appendectomy in children: a comparison of complications. *J Soc Laparoendosc Surg* 2000; **4**: 121–4.
26. Cauty TG, Collins D, Losasso B *et al.* Laparoscopic appendectomy for simple and perforated appendicitis in children: the procedure of choice? *J Pediatr Surg* 2000; **35**: 1582–5.
27. Krisher SL, Browen S, Dibbins A, Tkacz N, Ciurci M. Intra-abdominal abscess after laparoscopic appendectomy for perforated appendicitis. *Arch Surg* 2001; **136**: 438–41.
28. Meguerditchian A-N, Prasil P, Cloutier R *et al.* Laparoscopic appendectomy in children: a favorable alternative in simple and complicated appendicitis. *J Pediatr Surg* 2002; **37**: 695–8.
29. Lavonius MI, Liesjarvi S, Ovaska J, Pajulo O, Ristkari S, Alanen M. Laparoscopic versus open appendectomy in children: a prospective randomised study. *Eur J Pediatr Surg* 2001; **11**: 235–8.
30. Lejus C, Delile L, Plattner V *et al.* Randomized single-blinded trial of laparoscopic versus open appendectomy in children: effects on postoperative analgesia. *Anesthesiology* 1996; **84**: 801–6.
31. Lintula H, Kokki H, Vanamo K. Single-blind randomized clinical trial of laparoscopic versus open appendectomy in children. *Br J Surg* 2001; **88**: 10–4.
32. Little DC, Custer MD, May BH *et al.* Laparoscopic appendectomy: an unnecessary and expensive procedure in children? *J Pediatr Surg* 2002; **37**: 310–7.
33. El Ghoneimi A, Vall JS, Limmonne B *et al.* Laparoscopic appendectomy in children: report of 1,379 cases. *J Pediatr Surg* 1994; **29**: 786–9.
34. Gilchrist BF, Lobe TE, Schropp KP *et al.* Is there a role for laparoscopic appendectomy in pediatric surgery. *J Pediatr Surg* 1992; **27**: 209–14.
35. Sauerland S, Lefering R, Neugebauer EAM. Laparoscopic versus open surgery for suspected appendicitis. In: *The Cochrane Library*, Issue 1, 2002. Oxford: Update Software.
36. Shalaby R, Amos A, Desoky A, Samaha AH. Laparoscopic appendectomy in children: evaluation of different techniques. *Surg Laparosc Endosc Percut Tech* 2001; **11**: 22–7.
37. Collins JB, Georgeson KE, Vicente Y *et al.* Comparison of open and laparoscopic gastrostomy and fundoplication in 120 patients. *J Pediatr Surg* 1995; **30**: 1065–71.
38. Allal E, Captier G, Lopez M, Forgues D, Galifer R-B. Evaluation of consecutive laparoscopic funduplications in children: effect of the learning curve and technical choice. *J Pediatr Surg* 2001; **36**: 921–6.
39. Rothenberg S. Experience with 220 consecutive laparoscopic Nissen funduplications in infants and children. *J Pediatr Surg* 1998; **33**: 274–8.
40. Spitz L, Roth K, Kiely EM *et al.* Operation for gastro-oesophageal reflux associated with severe mental retardation. *Arch Dis Child* 1993; **68**: 347–51.
41. Siemer S, Humke U, Uder M *et al.* Diagnosis of impalpable testes in childhood: comparison of magnetic resonance imaging and laparoscopy in a prospective study. *Eur J Pediatr Surg* 2000; **10**: 114–8.
42. Lakhoo K, Thomas DF, Najmaldin AS. Is inguinal exploration for the impalpable testis and outdated operation? *Br J Urol* 1996; **77**: 452–4.
43. Humphrey GM, Najmaldin AS, Thomas DF. Laparoscopy in the management of the impalpable undescended testis. *Br J Surg* 1998; **85**: 983–5.
44. Chang B, Palmer LS, Franco I. Laparoscopic orchidopexy: a review of a large clinical series. *BJU Int* 2001; **87**: 490–3.
45. Lindgren BW, Franco I, Blick S *et al.* Laparoscopic Fowler-Stephens orchiopexy of the high intrabdominal testis. *J Urol* 1999; **162**: 990–3.
46. Clark DA, Borzi PA. Laparoscopic orchidopexy for the intra-abdominal testis. *Pediatr Surg Int* 1999; **15**: 454–6.
47. Esposito C, Vallone G, Settini A *et al.* Laparoscopic orchiopexy without division of the spermatic vessels: can it be considered the procedure of choice in cases of intra-abdominal testis? *Surg Endosc* 2000; **14**: 658–60.
48. Shalaby R, Desoky A. Needlescopic inguinal hernia repair in children. *Pediatr Surg Int* 2002; **18**: 153–6.
49. Schier F, Montupet P, Esposito C. Laparoscopic inguinal herniorrhaphy in children: a three centre experience with 933 repairs. *J Pediatr Surg* 2002; **37**: 395–7.
50. Esposito C, Montupet P. Laparoscopic treatment of recurrent inguinal hernia in children. *Pediatr Surg Int* 1998; **14**: 182–4.
51. Rowney DA, Aldridge IM. Laparoscopic fundoplication in children: anaesthetic experience of 51 cases. *Paediatr Anaesth* 2000; **10**: 291–6.
52. Gentili A, Iannettone CM, Pagna A *et al.* Cardiocirculatory changes during videolaparoscopy in children: an echocardiographic study. *Paediatr Anaesth* 2000; **10**: 399–406.
53. Sanada Y, Yamaguchi M, Chiba M *et al.* Endoscopic sphincterotomy and laparoscopic cholecystectomy in an infant with cholecysto-choledocholithiasis. *J Pediatr Surg* 1998; **33**: 1312–4.
54. Bozkurt P, Kaya G, Altinas F *et al.* Systemic stress response during operations for acute abdominal pain performed via laparoscopy or laparotomy in children. *Anaesthesia* 2000; **55**: 5–9.
55. Luks FJ, Logan J, Breuer CK *et al.* Cost-effectiveness of laparoscopy in children. *Arch Pediatr Adolesc Med* 1999; **153**: 965–8.
56. Blewitt CJ, Hollenbeak CS, Cilley RE, Dillon PW. Economic implications of current surgical management of gastroesophageal reflux disease. *J Pediatr Surg* 2002; **37**: 427–30.