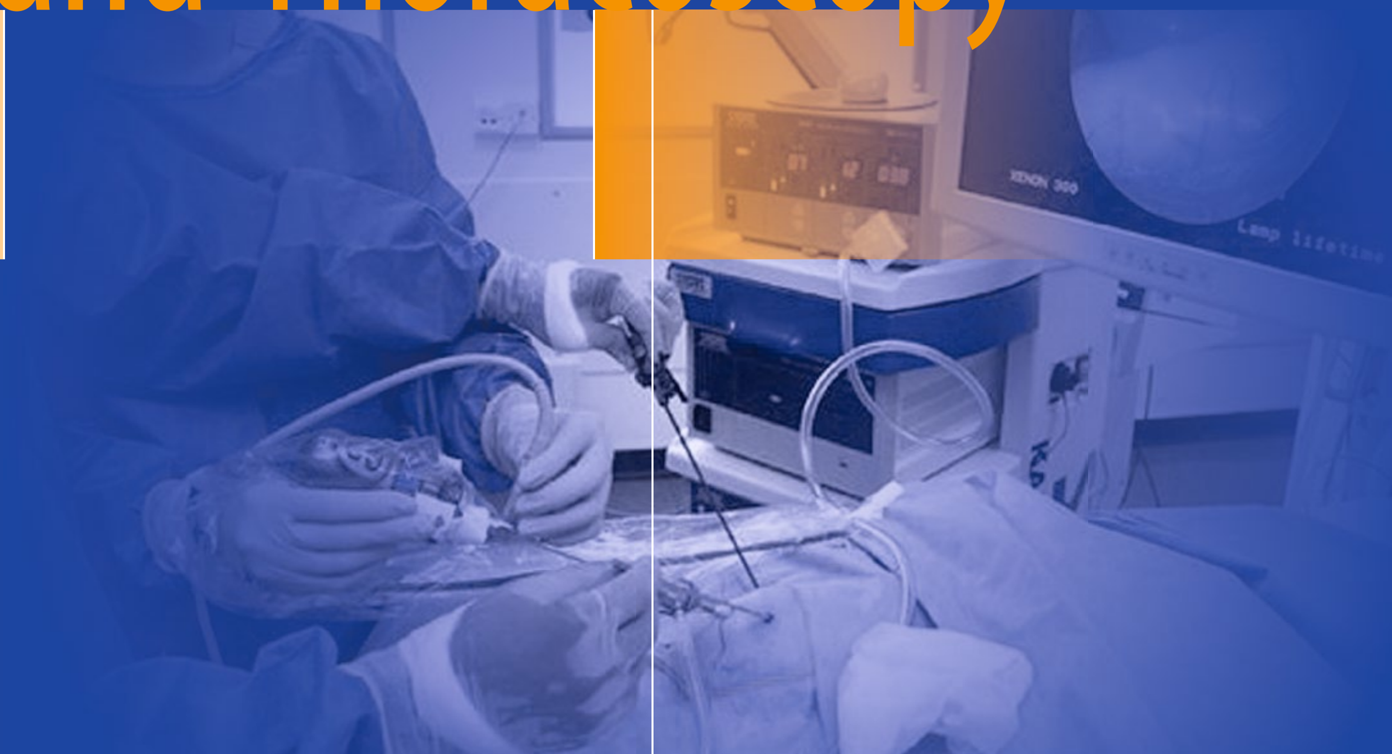
Merrill McHoney
Edward M. Kiely
Imran Mushtaq *Editors*

Color Atlas of Pediatric Anatomy, Laparoscopy, and Thoracoscopy



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Editors
Merrill McHoney
Paediatric Surgery
Royal Hospital for Sick Children Edinburgh
Edinburgh, United Kingdom

Imran Mushtaq
Great Ormond Street Hospital for Children
London, United Kingdom

Edward M. Kiely
Great Ormond Street Hospital for Children
London, United Kingdom

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Foreword

This beautifully illustrated Atlas will, I believe, prove invaluable to paediatric surgeons at all stages of their career. Those who are already proficient in minimal access surgery will find it useful in planning a new procedure as well as rehearsing more familiar ones. Trainees will benefit from it as they develop their surgical skills. Many paediatric surgeons have been slow to adopt minimal access techniques, continuing to perform "conventional" open surgery for most procedures. This book will hopefully stimulate those yet to be convinced, to ensure that they acquire the appropriate skills and adopt these techniques.

The authorship of this Atlas is international, from the United States, Europe, the Far East, and the United Kingdom, including, I am proud to note, several from Edinburgh, one of the first paediatric centres in the United Kingdom to pioneer these techniques. The operative stages of each procedure are clearly illustrated in a step-by-step sequence to aid understanding and facilitate successful completion of the entire operative procedure endoscopically.

Endoscopic surgery, mainly laparoscopy and thoracoscopy, not only offers benefit to the patient (improved cosmesis, less pain, less post-operative ileus, shorter hospital stay, faster recovery, etc.), but it is also advantageous to the surgeon. The view of the operative site, as seen in this Atlas, is usually far superior to that obtained through an open incision. The light is better and the magnification of the image on the screen gives a much clearer view of the detailed anatomy. I am certain that the next generation of paediatric surgeons will look back and say, "Did they really make those large, unsightly and disfiguring incisions when the same procedure can easily be performed using minimal access techniques?"

"In the 21st century it is unacceptable to perform any surgical procedure on a child by the open route if it can be safely and easily be carried out through minimal access surgery" (MacKinlay GA, BAPS Liverpool 1999). When I made this statement, it was considered heretical, but increasingly in the past two decades, the minimally invasive approach has evolved into routine paediatric surgical practice. This volume will likely become an essential component of every paediatric surgical department.

Edinburgh, UK — Gordon A. MacKinlay

Preface

We have been privileged to have worked with trainers and colleagues who have encouraged the development of minimally invasive surgery in children. The popularity of minimally invasive surgery in children is increasing, as well as the need for an atlas to help with the step-by-step approach to common operations, not only for those who are learning but also more advanced practitioners needing refreshing pictorial tips or reminders. This is not a textbook with details of disease pathology, clinical presentation, or even indications for surgery for each procedure. Instead, this atlas purely focuses on the operative steps once these steps have already been achieved. The impetus to edit this book has come from our desire to help students, trainees, and colleagues in developing minimally invasive surgery in children. We hope that this atlas will be of value to those who are developing those skills.

Contents

Contributors

Niyi Ade-Ajayi Department of Paediatric Surgery, King's College Hospital NHS Foundation Trust, London, UK

Khaled Ashour Department of Paediatric Surgery, John Radcliffe Hospital, Oxford University, Oxford, UK

Harish Chandran Department of Paediatric Surgery and Urology, Birmingham Children's Hospital, Birmingham, UK

Abraham Cherian Department of Paediatric Urology, Great Ormond Street Hospital, London, UK

Melanie Claire Clark Royal Hosptial for Sick Children, Edinburgh, UK

Simon A. Clarke Department of Pediatric Surgery, Chelsea and Westminster NHS Foundation Trust, London, UK

Kate Cross Paediatric Surgery Department, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

Khalid Elmalik Sheffield Children's Hosptial, Sheffield, UK

Bala Eradi Department of Paediatric Surgery, Leicester Royal Infirmary, Leicester, UK

Aimee Gibson Paediatric Surgery, Gold Coast University Hospital, Queensland, Australia

Hugh W. Grant Department of Paediatric Surgery, John Radcliffe Hospital, Oxford University Hospitals, Oxford, Oxfordshire, UK

Philip Hammond Royal Hosptial for Sick Children, Edinburgh, UK

Kokila Lakhoo Department of Paediatric Surgery, Oxford Children's Hospital, Oxford University Hospitals and University of Oxford, Oxford, UK

Jimmy Lam Department of Paediatric Surgery, Royal Hospital for Sick Children, Edinburgh, UK

Alex C.H. Lee Department of Paediatric Surgery, Oxford University Hospitals NHS Trust, Level 2, Oxford Children's Hospital, John Radcliffe Hospital, Oxford, UK

Marc A. Levitt The Ohio State University, Columbus, OH, USA

Nationwide Children's Hospital, Columbus, OH, USA

Nguyen Thanh Liem Vinmec International Hospital, Hanoi, Vietnam

Brian MacCormack Department of Paediatric Surgery, Royal Hospital for Sick Children, Edinburgh, UK

Gordon A. MacKinlay Royal Hospital for Sick Children, Edinburgh, UK

Sean Marven Sheffield Children's Hostpial, Sheffield, UK

Amanda J. McCabe Department of Paediatric Surgery, Royal Hospital for Sick Children, Edinburgh, UK

Merril McHoney Department of Paediatric Surgery, Royal Hospital for Sick Children, Edinburgh, UK

Pankaj Kumar Mishra Department of Paediatric Urology, Great Ormond Street Hospital, London, UK

Fraser D. Munro Department of Paediatric Surgery, Royal Hospital for Sick Children, Edinburgh, UK

Maurizio Pacilli Department of Paediatric Surgery, Oxford University Hospital, Oxford, UK

Dakshesh H. Parikh Department of Paediatric Surgery, Birmingham Children's Hospital NHS FT, Birmingham, UK

Shabnam Parkar Department of General Paediatric Surgery, Chelsea Children's Hospital, Chelsea and Westminster Hospital, London, UK

Ashok Daya Ram Department of Paediatric Surgery, Birmingham Children's Hospital, Birmingham, UK

Melissa Short Department of Paediatric Surgery, Birmingham Children's Hospital, Birmingham, UK

Michael Singh Department of Paediatric Surgery, Birmingham Children's Hospital, Birmingham, England

Vassilis J. Siomos Department of Surgery-Urology, University of Colorado Hospital, Children's Hospital Colorado, Aurora, CO, USA

Naima Smeulders Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

Giampiero Soccorso Birmingham Children's Hospital NHS Foundation Trust, Birmingham, UK

Michael Stanton Department of Paediatric Surgery, G Level, Southampton Children's Hospital, Southampton, UK

Joanna Stanwell Department of Paediatric Surgery, University Hospital Southampton NHS Foundation Trust, Southampton, UK

Nada Sudhakaran Paediatric Surgery, Gold Coast University Hospital, Queensland, Australia

Robert Wheeler University Hospital Southampton NHS Foundation Trust, Southampton, Hampshire, UK

Cole Wiedel Department of Surgery-Urology, University of Colorado Denver School of Medicine, University of Colorado Hospital, Children's Hospital Colorado, Aurora, CO, USA

Duncan T. Wilcox Department of Pediatric Urology, Children's Hospital Colorado, Aurora, CO, USA

Malcolm Wills Department of Cardiothoracic Surgery, Royal Infirmary of Edinburgh, Edinburgh, UK

Francisca Yankovic Department of Paediatric Urology, Great Ormond Street Hospital NHS Foundation Trust, London, UK

Augusto Zani Division of General and Thoracic Surgery, The Hospital for Sick Children, Toronto, ON, Canada

1 Introduction and General Principles

Merrill McHoney, Edward Kiely, and Imran Mushtaq

Abstract

Minimally invasive surgery (MIS) has become relatively commonplace in paediatric surgery, and is becoming more popular. Paediatric surgeons perform laparoscopic and thoracoscopic surgery with the commonly held belief that MIS is associated with a dampened stress response, more rapid postoperative recovery, and early discharge from hospital. There are also long-term cosmetic advantages. Depending on the operation in question, some of the potential advantages hold, but others do not, and we need to be conscious of potential disadvantages and difficulties when embarking on MIS.

Keywords

Minimally invasive surgery • Laparoscopy • Thoracoscopy • Retroperitonoscopy • Children

Minimally invasive surgery (MIS) has become relatively commonplace in paediatric surgery, and is becoming more popular. Paediatric surgeons perform laparoscopic and thoracoscopic surgery with the commonly held belief that MIS is associated with a dampened stress response, more rapid postoperative recovery, and early discharge from hospital. There are also long-term cosmetic advantages. Depending on the operation in question, some of the potential advantages hold, but others do not, and we need to be conscious of potential disadvantages and difficulties when embarking on MIS.

As an introduction to the rest of this atlas, this chapter discusses some of these issues (albeit very briefly) in addressing the "Why, When, Who, Where, and How" of MIS in children.

M. McHoney (✉)
Department of Paediatric Surgery, Royal Hospital for Sick Children, Edinburgh, UK

E. Kiely
Department of Paediatric Surgery, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

I. Mushtaq
Department of Pediatric Urology, Great Ormond Street Hospital for Children NHS Trust, London, UK

1.1 Why Minimally Invasive Surgery in Children?

We can address the reasons for performing MIS surgery in children by thinking of the advantages or benefits of MIS, but we will also touch on the risks and potential downfalls. There is evidence for some of the perceived benefits of MIS in children, but some aspects lack substantial evidence at the moment. The evidence base is increasingly being accrued and investigated, however, and a few operations have been evaluated in randomised controlled trials [1].

1.1.1 Potential Benefits

1.1.1.1 Postoperative Pain and Recovery

Both thoracoscopy and laparoscopy are associated with a significant reduction in the amount of tissue trauma and thereby a reduction in postoperative pain. Studies have shown varying reductions in postoperative pain after MIS in both adults and children. Clinical evidence in adults shows that laparoscopic surgery reduces postoperative stay, respiratory complications, and postoperative pain when compared with open surgery [2, 3]. The decreased postoperative pain of tissue trauma after laparoscopy must

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be balanced with the possibility of shoulder tip pain, perhaps accounting for the fact that decreased postoperative pain is not always proven. Laparoscopic surgery for moderate to severely invasive operations has proven quicker recovery in many studies. Thoracoscopy in children greatly improves postoperative recovery [4, 5] and the minimisation of postoperative pain.

1.1.1.2 Cosmetic Advantages

The improved cosmesis after MIS is one of the hardest advantages to quantify and report. The exchange of large laparotomy and thoracotomy incisions for keyhole incisions is undeniably beneficial. The minimisation of the visible scar associated with the incisions in an important long-term advantage to patients.

Reduction of physical deformity, especially on the chest wall, is also very important. Long-term chest wall deformity is minimised by MIS, and sometimes is eliminated completely. Winging of the scapula, kyphoscoliosis, pectus deformities, and other deformities seen after thoracotomy are reduced by thoracoscopy [6, 7]. Although most often associated with chest wall incisions, such deformities also can be associated with large abdominal wall incisions.

1.1.1.3 Blunting of the Metabolic Response

MIS is associated with minimisation of the degree of tissue trauma (as the incisions into the body wall are smaller than in the comparable open operation) and is of benefit in reducing some of the postoperative complications by blunting of the metabolic and stress response. The cytokine response is reduced after operations of a major magnitude performed by MIS [8–10]. One of the major determinants of the metabolic response to surgery is the magnitude of the operative stress [11, 12]. Operations of greater magnitude are associated with a greater metabolic response [13]. Therefore the benefit is more pronounced when bigger operations are performed by MIS.

1.1.1.4 Thermoregulation and Energy Metabolism

There is an important association between alteration in thermoregulation and the metabolic response. In the 1960s, it was demonstrated that maintaining a 30 °C environmental temperature blunted the metabolic response to trauma and could therefore play an important role in determining the postoperative metabolic response [14]. Morbidity and mortality were also influenced by thermoregulation. Infants and children are more susceptible to alterations in thermoregulation and environmental temperature than adults. Physiological differences in thermoregulation may be partially responsible for differences between neonates, children, and adults in patterns of metabolic response.

Because MIS is not associated with large open wounds, heat loss and evaporative water loss are prevented, in turn altering thermoregulation. Studies have shown maintenance of core temperature and oxygen consumption in children undergoing thoracoscopy [15, 16] and laparoscopy [17], which was more marked in younger and smaller children. Changes in intraoperative thermoregulation may alter postoperative metabolism and changes in energy expenditure.

Luo et al. performed a trial in adults randomised to open or laparoscopic cholecystectomy [18]. Rest energy expenditure (REE), as measured by indirect calorimetry, was elevated on postoperative day 1 in both groups, but the rise in REE was significantly higher in the open group than in the laparoscopic group. Postoperative energy metabolism is also altered by laparoscopy in children, with a preservation of energy metabolism in comparison with open surgery [19]. There are possible effects on postoperative protein metabolism alongside these alterations. It seems, therefore, that MIS is associated with preservation of homeostasis with regard to energy expenditure.

1.1.1.5 Visualisation and Magnification

The visualisation obtained with MIS is often superior to visualisation with open surgery. Access to many deep recesses and folds can be improved with the use of the scope. For instance, access to the oesophageal hiatus, pelvic structures, and apical areas of the lung is greatly facilitated with MIS, compared with open surgery.

A much greater degree of magnification also can be obtained using MIS. Structures that may be difficult to see with the naked eye (e.g., the vagus nerve and its branches during fundoplication and oesophageal atresia repair) are often easily visible on the screen with the optical and digital magnification allowed with MIS.

1.1.2 Potential Hazards of MIS

1.1.2.1 Carbon Dioxide Absorption from the Surgical Cavity

One of the new dimensions introduced by MIS is the creation of a working space. This technique can involve abdominal wall lifting, but the method most commonly used is insufflation of CO_2 to create a capnoperitoneum (or capnothorax). CO_2 absorbed from the body cavity during MIS causes an increase in CO_2 elimination via the lungs. In adults undergoing laparoscopy, there is typically a brief period of increased CO_2 elimination, but after 10–30 min of insufflation, a plateau is usually reached [20]. In children, the CO_2 profile is different: there is a continuous increase in CO_2 elimination throughout intraperitoneal insufflation of CO_2 in children [21]. The increase in CO_2 elimination was more marked in younger and smaller children, suggesting that age modifies the intraoperative handling of CO_2, and the same difference was true for thoracoscopic surgery [15]. The increased CO_2 load has been calculated to be approximately 16 % accounted for by absorption from the abdomen in one study [22]. In the case of thoracoscopy, nearly 50 % of expired CO_2 is absorbed from the thorax [22].

Neonates are particularly prone to acidosis during thoracoscopic surgery owing to the markedly increased CO_2 load, the decreased respiratory elimination from lung collapse, and exaggerated absorption in smaller children [15, 21]. Patients with congenital diaphragmatic hernia, for instance, are also at risk of significant acidosis and secondary effects [23–25]. Thoracoscopic surgery therefore should not be performed without suitable expertise and monitoring, or if the patient is unstable.

1.1.2.2 Mechanical Effects of Carbon Dioxide Insufflation

Insufflation of CO_2 used during laparoscopy increases intra-abdominal pressure. The optimal intra-abdominal pressure for laparoscopy in children has been established to be between 8 and 12 mm Hg [26], with neonates tolerating lower pressures than older children. The increase in intra-abdominal pressure causes a rise in intrathoracic pressure, which alters respiratory dynamics and leads to impaired respiratory function, including reduced functional residual capacity, increased airway pressure, and decreased lung compliance. Absorption of CO_2 from the abdomen seems to peak about 30 min into surgery, with up to 20 % of expired CO_2 derived from absorption; it decreases back to preoperative levels 30 min postoperatively [27]. During laparoscopy in self-ventilating patients, this change translates into an increase in end-tidal CO_2 and arterial CO_2 tensions [28] that can lead to acidosis.

In children undergoing controlled ventilation during laparoscopy, there is generally a good correlation between end-tidal CO_2 and arterial CO_2 pressures ($PaCO_2$) [28, 29]. If ventilation parameters are maintained at pre-insufflation values, both end-tidal CO_2 and $PaCO_2$ increase as intra-abdominal pressure increases. Occasionally, the increase in $PaCO_2$ is out of step with the increase in end-tidal CO_2 [30]. A 20–30 % increase in minute ventilation is usually sufficient to compensate for the increased CO_2 load [31–33], thus avoiding an increase in end-tidal CO_2 or acidosis.

Intra-thoracic insufflation of CO_2 has different mechanical effects on respiratory dynamics than intra-abdominal insufflation. Greater impaired respiratory capacity imposed by lung collapse has significant implications for oxygenation and CO_2 excretion [34]. Thoracic insufflation of CO_2 may also have a different absorption profile than abdominal insufflation, as it seems not to reach steady state within 30 min [23]. A greater percentage (up to 30 %) of exhaled CO_2 is derived from absorption during thoracoscopy, compared with 20 % during laparoscopy. The greater absorption of CO_2 insufflated into the chest, coupled with the impaired ventilation, can lead to a marked increase in arterial CO_2 concentration, which is especially of concern in neonates and smaller children, who have been shown to have greater CO_2 increases than bigger children [15]. Acidosis can be severe and prolonged in neonates undergoing thoracoscopy [23, 24]. The ability to increase CO_2 excretion in the face of the increased load created by its absorption is crucial to safe thoracoscopy in children. To avoid harm, the anaesthetist must anticipate, monitor, and expertly manage this requirement. Therefore thoracoscopic surgery in these circumstances should be performed only in experienced centres and with good prospective monitoring and management of CO_2 load.

1.1.2.3 Learning Curve

The impact of learning new tasks needed for MIS must be taken account in embarking on such a venture. Many skills are of course transferable between operations, but not always between open and laparoscopic surgery. Intracorporeal suturing is a part of some MIS procedures and must be learned before embarking on operations requiring this technique. There is a role for learning these basic skills first on a form of trainer (of which there are several types available), before or while simultaneously attending a basic course. More advanced courses teaching the combined steps and skills for specific and advanced operations also can be used. Many training models have been developed for specific operations.

Whereas the learning curve can be measured in terms of operative time and hospital stay, better measures are patient safety outcomes such as complications and recurrence rates. Many MIS operations can take significantly longer than the corresponding open operation, especially during the learning curve. This difference must be appreciated by the surgeon, anaesthetist, and theatre staff (as well as patients and family, of course), for good teamwork and success. For most surgeons with advancing skills, however, this difference in time taken lessens and becomes clinically (and occasionally actually) insignificant.

There are various estimates of the number of MIS procedures required to reach the peak of the learning curve. For example, the number of procedures needed for laparoscopic hernia repair is estimated to be between 10 and 30 cases [35, 36]. It must be remembered, however, that the learning curve is both surgeon-specific and procedure-specific.

Being mentored at the outset of the MIS venture is one means of quickly and safely negotiating the learning curve. Inviting experienced operators to mentor surgeons at the beginning of their venture should facilitate quick and safe advancement up the learning curve.

1.2 When Should MIS Be Used in Children?

1.2.1 Indications and Contraindications

More and more operations are being performed by MIS in children. Indications for each specific operation are beyond the scope of this book. Some general indications and contraindications can be given.

1.2.2 Specific Operations

Some operations lend themselves nicely to MIS. Operations that are particularly suitable for MIS may have the following characteristics:

- A small, focused area of interest that would otherwise require a large incision for access (e.g., the oesophageal junction for myotomy or fundoplication)
- Access to areas that are relatively difficult to reach (e.g., deep recesses) but are suitable for access with a scope (e.g., operations around the oesophageal hiatus or pelvis)
- Operations that have incisions associated with poor cosmetic outcome (e.g., chest wall deformity) but that can be improved with MIS
- Operations in which diagnostic uncertainty exists or when MIS offers opportunity for diagnostic benefit not easily available with open surgery (e.g., assessment of contralateral inguinal ring and pelvic organs in hernia surgery, and investigation of impalpable testis)

Some operations may pose a relative or absolute contraindication to MIS, but absolute contraindications are becoming fewer with advancing experience, instrumentation, and innovation. Contraindications are suggested by the following considerations:

- If the MIS approach is associated with higher complication rates, it is contraindicated.
- The MIS approach can be sanctioned for cancer surgery only if the cancer surgery principles can be adhered to (e.g., nodal sampling or clearance, wide tumour margins, and intact tumour retrieval without rupture).
- If MIS ports do not allow safe organ or specimen retrieval, open surgery may be needed. Often hybrid techniques are possible, however (e.g., see Splenectomy chapter), using alternative innovations or techniques or a more appropriate abdominal incision.
- The need to alter the steps of the "classic" open operation is often cited as a contraindication for laparoscopic surgery—an idea both correct and incorrect. Often various innovations in instrumentation and technique allow the MIS operation to be performed using the classic steps, and this should be the first intention. But in other operations, the outcome is equivalent even though the classic steps of an open operation are not performed laparoscopically. The key consideration is whether the efficacy and outcome of the laparoscopic approach have been shown to be equal to those of the open approach.

1.2.3 Clinical Status

Patients being considered for MIS should be specifically clinically evaluated for the potential physiological changes discussed previously. In general, they should have achieved some physiological stability, if not normality. Emergency operations in unstable patients are associated with higher rates of complications. Active bleeding is a relative contraindication for MIS, as bleeding will severely obscure visualisation in the cavity being explored. Furthermore, blood itself causes difficulty by light absorption, thereby further decreasing visibility.

There is no age or weight limit for the application of MIS in children. Even preterm neonates can be candidates for diagnostic and therapeutic interventions, and even operations requiring advanced MIS skills are being performed in younger and smaller children.

There are some contraindications:

- Inability to tolerate the additional challenges of MIS surgery and the CO_2 load required, as shown by evaluation
- Active bleeding (relative)
- Physiological instability—a relative contraindication but an important parameter that may prevent MIS

1.3 Who Should Perform MIS in Children?

1.3.1 Training and Competence

Not all surgeons may suit advanced MIS surgery and the skill sets that are required, but with adequate training, nearly every surgeon can perform simple MIS procedures or operations. Many models of training exist and a combination of some or all is usually employed in a stepwise fashion.

- Simple box trainers allow the novice MIS surgeon to test, evaluate, and develop the skills required. Simple box trainers may also employ a manual or electronic scoring system to allow documentation (and audit) of the developing psychomotor skills. An example of a simple box trainer used in one of our centres is shown in Fig. 1.1. Box training has been shown to successfully contribute to laparoscopic competence [37].
- Complex box trainers allow the trainee to develop the sometimes more complex mix of the many different skills and techniques required during MIS. Acquisition of data regarding developing skills is again possible.
- Specific training models for specific operations also exist, simulating the steps required for the completion of an operation from start to finish. For example, box trainers exist for operations such as repair of inguinal hernia, pyloric stenosis, diaphragmatic hernia, or oesophageal atresia and tracheo-oesophageal fistula. These models can use a combination of simulated reconstructions and realistic body cavities with simulated tissue.
- Training courses are a very good means of gaining exposure to MIS surgery. Courses are available at a variety of levels, from those targeted at the novice and most junior trainee to advanced courses for established MIS surgeons. Some of the advanced courses allow realistic exposure to animal tissue or models (including live operating) with expert tutorship and teaching.
- Clinical exposure is the most realistic and eventually the most appropriate means of training, but the need for clinical training and clinical governance must be balanced with patient safety and outcome. Therefore some form of training with the means described above is used prior to and alongside clinical exposure.

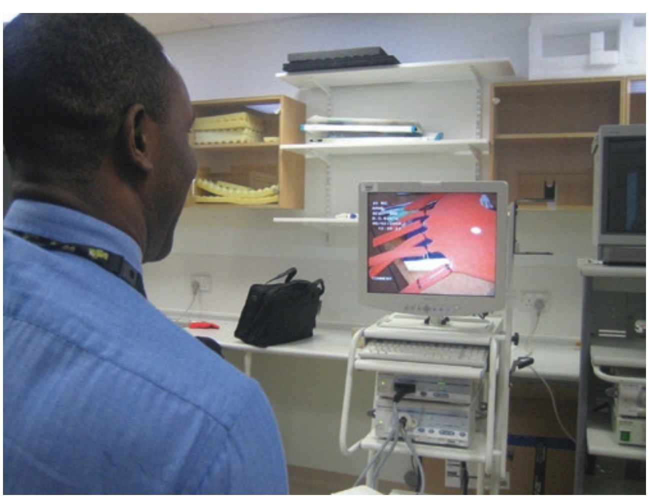

Fig. 1.1 A simple box trainer used in one of our centres

1.3.2 Mentorship

This can be seen as the final training step for those wishing to embark on MIS who have not acquired full training in MIS or in a specific operation. An expert can mentor a senior surgeon in the acquisition of the final stages of the needed skill and experience. This mentorship allows for a good mix of training, governance, and safety.

1.3.3 Continued Development

Even experts in MIS needs to continually develop and modify techniques and skills, keeping abreast of advances in the field. This development is often best done by attending large international conferences that either focus on MIS (e.g., International Pediatric Endosurgery Group/Society of American Gastrointestinal and Endoscopic Surgeons, IPEG/SAGES) or include MIS in their programme (e.g., British Association of Paediatric Surgeons/British Association of Urological Surgeons, BAPS/BAUS), often with manual training running alongside academic sessions.

It is also prudent to audit and frequently evaluate the outcome of MIS cases to document and evaluate outcomes that may need addressing or can help direct continued professional development. Presenting such data at conferences is also a means of peer review and feedback, which can help continued professional development.