Principles of laparoscopic and robotic surgery

Learning objectives
To understand:
• The principles of laparoscopic and robotic surgery
• The advantages and disadvantages of such surgery
• The safety issues and indications for laparoscopic and robotic surgery
• The principles of postoperative care

DEFINITION
Minimal access surgery is a product of modern technology and surgical innovation that aims to accomplish surgical therapeutic goals with minimal somatic and psychological trauma. This type of surgery has reduced wound access trauma, as well as being less disfiguring than conventional techniques. It can offer cost-effectiveness to both health services and employers by shortening operating times, shortening hospital stays, improving operative precision compared to open surgery in some (but not all) cases and allowing faster recuperation.

EXTENT OF MINIMAL ACCESS SURGERY
The first introduction of an experimental laparoscopic procedure was by Georg Kelling of Dresden in 1901 (he termed it 'celioscopy' and used a Nitze-cystoscope). This was followed by Hans Christian Jacobaeus’ successful application in humans in Sweden. Despite the work of these pioneers, it took another 70 years before Patrick Steptoe applied this approach to patients in the United Kingdom in 1980, and Phillipe Mouret’s first video-laparoscopic cholecystectomy was performed in Lyon, France in 1987. However, since its mainstream adoption in the mid-1990s, minimal access surgery has crossed all traditional boundaries of specialties and disciplines. Shared, borrowed and overlapping technologies and information are encouraging a multidisciplinary approach that serves the whole patient, rather than a specific organ system.

The core principles of minimal access surgery (independent of procedure or device) can be summarized by the acronym I-VITROS:
• Insufflate/create space – to allow surgery to take place in the minimal access setting
• Visualise – the tissues, anatomical landmarks and the environment for the surgery to take place
• Identify – the specific structures for surgery
• Triangulate – surgical tools (such as port placement) to optimise the efficiency of their action, and ergonomics by minimising overlap and clashing of instruments
• Retract – and manipulate local tissues to improve access and gain entry into the correct tissue planes
• Operate – incise, suture, anastomose, fuse
• Seal/haemostasis.

Broadly speaking, minimal access techniques can be categorised as follows:

Laparoscopy
A rigid endoscope (laparoscope) is introduced through a port into the peritoneal cavity. This is insufflated with carbon dioxide to produce a pneumoperitoneum. Further ports are inserted to enable instrument access and their use for dissection (Figure 8.1). It is generally accepted that laparoscopic cholecystectomy has revolutionised the surgical management of cholelithiasis and has become the mainstay of management of uncomplicated gallstone disease. With improved instrumentation, advanced procedures, such as laparoscopic colectomies for malignancy, previously regarded as controversial, have also become fully accepted. There continues to be substantive evidence demonstrating the short-term benefits of laparoscopic surgery over open surgery with regard to postoperative pain, length of stay and earlier return to normal activities; however, the equivalence of the benefits in long-term outcomes, such as oncological quality and cancer-related survival, has not been established.
Thoracoscopy
A rigid endoscope is introduced through an incision in the chest to gain access to the thoracic contents. Usually there is no requirement for gas insufflation, as the operating space is held open by the rigidity of the thoracic cavity. In specific cases, such as mediastinal tumour resection and diaphragmatic surgery, gas insufflation at low pressure (5–8 mmHg) may be applied.

Endoluminal endoscopy
Flexible or rigid endoscopes are introduced into hollow organs or systems, such as the urinary tract, upper or lower gastrointestinal tract, and respiratory and vascular systems.

Perivisceral endoscopy
Body planes can be accessed even in the absence of a natural cavity. Examples are mediastinoscopy, retroperitoneal and retroperitoneal approaches to the kidney, aorta and lumbar sympathetic chain. Extraperitoneal approaches to the retroperitoneal organs, as well as hernia repair, are now becoming increasingly commonplace, further decreasing morbidity associated with visceral peritoneal manipulation. Other, more recent, examples include subfascial ligation of incompetent perforating veins in varicose vein surgery.

Arthroscopy and intra-articular joint surgery
Orthopaedic surgeons have applied arthroscopic access to the knee for some time and are applying this modality to other joints, including the shoulder, wrist, elbow and hip.

Combined approach
The diseased organ is visualised and treated by an assortment of endoluminal and extraluminal endoscopes and other imaging devices. Examples include the combined laparoscopic approach for the management of biliary lithiasis, colonic polyp excision and several urological procedures, such as pyeloplasty and donor nephrectomy. In some cases the application of this combined approach offers the ability to execute operations via a single incision, thereby better adhering to the minimally invasive approach. The evidence for improved outcomes using these combined approaches remains limited for the majority of procedures.

SURGICAL TRAUMA IN OPEN, MINIMALLY INVASIVE AND ROBOTIC SURGERY
Most of the trauma of an open procedure is inflicted because the surgeon must have a wound that is large enough to give adequate exposure for safe dissection at a target site. The wound is often the cause of morbidity, including infection, dehiscence, bleeding, herniation and nerve entrapment. Wound pain prolongs recovery time and, by reducing mobility, contributes to an increased incidence of pulmonary atelectasis, chest infection, paralytic ileus and deep venous thrombosis.

Mechanical and human retractors cause additional trauma. Body wall retractors can inflict localised damage that may be as painful as the wound itself. In contrast, during laparoscopy, the retraction is provided by the low-pressure pneumoperitoneum, giving a diffuse force applied gently and evenly over the whole body wall, causing minimal trauma.

Exposure of any body cavity to the atmosphere also causes morbidity through cooling and fluid loss by evaporation. There is also evidence that the incidence of postsurgical adhesions has been reduced by the use of the minimally invasive (laparoscopic, thoracoscopic) and robotic approaches, which has been suggested to result from less damage to delicate serosal coverings. In the manual handling of intestinal loops, the surgeon and assistant disturb the peristaltic activity of the gut and provoke adynamic ileus.
Minimal access surgery has many advantages, such as a reduction in the trauma of access and exposure and an improvement in visualisation. While minimal access methods have been an established modality in some elective surgical procedures, they are now also being increasingly applied with success in emergency surgical procedures (including perforated viscus repair, such as omental patch repair of the stomach, and washout of localised perforation of diverticular disease).

**Summary box 8.1**

**Advantages of minimal access surgery**
- Decrease in wound size
- Reduction in wound infection, dehiscence, bleeding, herniation and nerve entrapment
- Decrease in wound pain
- Improved mobility
- Decreased wound trauma
- Decreased heat loss
- Improved visualisation

**LIMITATIONS OF MINIMAL ACCESS SURGERY**

Despite its many advantages, minimal access surgery has its limitations. To perform minimal access surgery with safety, the surgeon must operate remote from the surgical field, using an imaging system that provides a two-dimensional (2D) representation of the operative site. The endoscope offers a whole new anatomical landscape, which the surgeon must learn to navigate without the usual ‘open approach’ clues that make it easy to judge depth. The instruments are longer and sometimes more complex to use than those commonly used in open surgery. This results in the novice being faced with significant problems of hand–eye coordination. Here there is a well-described learning curve for novice surgeons and experienced ‘open’ surgeons when adopting the minimally invasive approach.

Some of the procedures performed by these new approaches are more technically demanding and are slower to perform, and they often have a more difficult learning curve as tactile feedback to the surgeon is lost. Indeed, on occasion, a minimally invasive operation is so technically demanding that both patient and surgeon are better served by conversion to an open procedure. Unfortunately, there seems to be a sense of shame associated with conversion, which is quite unjustified. It is vital for surgeons and patients to appreciate that the decision to close or to convert to an open operation is not a complication but, instead, usually implies sound surgical judgement in favour of patient safety.

Another problem occurs when there is intraoperative arterial bleeding. Haemostasis may be very difficult to achieve endoscopically because blood obscures the field of vision and there is a significant reduction of the image quality due to light absorption.

Another disadvantage of laparoscopic surgery is the loss of tactile feedback in the context of some procedures (although many procedures have been successfully performed without ‘traditional sense’ of tactile feedback). This is an area of ongoing research in haptics and biofeedback systems. Early work suggested that laparoscopic ultrasonography might be a substitute for the need to ‘feel’ in intraoperative decision-making. The rapid progress in advanced laparoscopic techniques, including biliary tract exploration and surgery for malignancies, has provided a strong impetus for the development of laparoscopic ultrasound. Now more developed, this technique already has advantages that far outweigh its disadvantages.

In more advanced techniques, large pieces of resected tissue, such as the lung or colon, may have to be extracted from the body cavity. Occasionally, the extirpated tissue may be removed through a nearby natural orifice, such as the rectum or the mouth. At other times, a novel route may be employed. For instance, a benign colonic specimen may be extracted through an incision in the vault of the vagina. Several innovative tube systems have been shown to facilitate this extraction. Although tissue ‘morcellators, mincers and liquidisers’ can be used in some circumstances, they have the disadvantage of reducing the amount of information available to the pathologist. Previous reports of tumour implantation in the locations of port sites raised important questions about the future of the laparoscopic treatment of malignancy, but large-scale trials have shown this claim to be false. Although emerging evidence from large-scale international prospective trials implicates surgical skill as an important aetiological factor, it is important to consider the biological implications of minimally invasive strategies on the tumours. The use of carbon dioxide and helium as insufflants causes locoregional hypoxia and may also change pH. The resultant modulation of the behaviour of spilled tumour cells is increasingly being studied, although the risks of recurrence at port sites seem to be minimised by appropriate tissue handling, separating any tumours by bagging, and washing and protecting the site.

Hand-assisted laparoscopic surgery is a well-developed technique. It involves the intra-abdominal placement of a hand or forearm through a minilaparotomy incision, while pneumoperitoneum is maintained. In this way, the surgeon’s hand can be used as in an open procedure. It can be used to palpate organs or tumours, reflect organsatraumatically, retract structures, identify vessels, dissect bluntly along a tissue plane and provide finger pressure to bleeding points, while proximal control is achieved. This approach has been suggested to offer technical and economic efficiency when compared with a totally laparoscopic approach, in some instances, reducing both the number of laparoscopic ports and the number of instruments required. Some advocates of the technique claim that it is also easier to learn and perform than totally laparoscopic approaches, and that there may be increased patient safety.

There has been a continued improvement in dissection techniques in laparoscopic/thoracoscopic surgery beyond that of standard electrosurgery/diathermy and laser technology to improve dissection precision and haemostatic efficacy. Ultrasonic dissection, tissue fusion devices and tissue removal continue to be adopted across specialties and practitioners. This has taken place as a consequence of continuous and incremental technical improvements in devices, increased
familiarity with their use and some improvements in cost of access. The adaptation of the technology to minimally invasive surgery grew out of the search for alternative, possibly safer, methods of dissection. Some current units combine the functions of three or four separate instruments, reducing the need for instrument exchanges during a procedure. This flexibility, combined with the ability to provide a clean, smoke-free field, has the potential to improve safety and shorten operating times.

Although dramatic cost savings are possible with laparoscopic cholecystectomy when compared with open cholecystectomy, the position was less clear-cut with other procedures initially. There is another factor that may complicate the computation of the cost–benefit ratio. A significant rise in the rate of cholecystectomy followed the introduction of the laparoscopic approach because the threshold for referring patients for surgery became lower. The increase in the number of procedures performed has led to an overall increase in the cost of treating symptomatic gallstones.

Three-dimensional (3D) imaging systems have been available for some time, but remain expensive and currently are not commonplace, partially because many surgeons feel that 3D technology has not yet offered the ability to perform procedures with significant technical enhancement or to improve safety or outcomes across a range of operations. Stereoscopic imaging for laparoscopy and thoracoscopy is still progressing. Future improvements in these systems carry the potential to enhance manipulative ability in critical procedures, such as knot tying and dissection of closely overlapping tissues. There are, however, some drawbacks, such as reduced display brightness and interference with normal vision because of the need to wear specially designed glasses for some systems. It is likely that brighter projection displays will be developed, at increased cost. However, the need to wear glasses will not be easily overcome.

Looking further to the future, it is evident that the continuing reductions in the costs of elaborate image-processing techniques will result in a wide range of transformed presentations becoming available. It should ultimately be possible for a surgeon to call up any view of the operative region that is accessible to a camera and present it stereoscopically in any size or orientation, superimposed on past images taken in other modalities. Such augmented reality systems have been available for several years but continue to improve. It is for the medical community to decide which of these many potential imaginative techniques will contribute most to effective surgical procedures.

**Summary box 8.2**

Limitations of minimal access surgery
- Reliance on remote vision and operating
- Loss of tactile feedback
- Dependence on hand–eye coordination
- Difficulty with haemostasis
- Reliance on new techniques
- Extraction of large specimens

**ROBOTIC SURGERY**

A robot is a mechanical device that performs automated physical tasks according to direct human supervision, a predefined program or a set of general guidelines, using artificial intelligence techniques. In terms of surgery, robots have been used to assist surgeons during procedures. This has been primarily in the form of automated camera systems and telemanipulator systems, thus resulting in the creation of a human–machine interface.

Even though laparoscopic surgery has progressed greatly over the last two decades, owing to its widespread use and dissemination in that time, there are, as discussed above, limitations. To those already mentioned may be added reduced degrees of freedom of movement and ergonomically difficult positions for the surgeon. Such problems undoubtedly affect surgical precision. This has led to interest in robotic surgical systems, which currently exist as two main categories:

- **Teleoperated systems:** a human surgeon performs an operation via a robot and its robotic instruments through a televiual computerised platform, either via onsite connections or remotely through the internet or other digital channels – hence the publicity of ‘operating on a patient from another country’ (such ‘remote’ operations are currently rarely performed but their existence is established).
- **Image-guided systems:** A surgical robot completes a preprogrammed surgical task which is guided by preoperative imaging and real-time anatomical constraints and cues through the application of inbuilt navigation systems.

In the current era the concept of the master–slave system prevails (where the surgeon is the master, i.e. the operator, and the robot is the slave). The two are linked by underlying hardware and software components within an advanced computer construction. Such devices have been available for the past 30 years and have become more available during the past two decades. They still remain a relative rarity owing to a multitude of factors including cost, applicability and benefits for a particular operation/pathology, training requirements and the support that is necessary, beyond just that of the individual surgeon but rather at whole institution level.

Since their first clinical use in 1985, with the PUMA 560 being used for a brain biopsy, surgical robots have been considered to offer many benefits, which have arisen as a result of new technology in lenses, cameras and computer software. Just as laparoscopic surgery benefited from advances in light technology, allowing the targeted transmission of light down tubing, robotic surgery benefited from computer integration of mechanical (surgical) arms that paved the way for computer-integrated surgery (CIS). The advantages of robotic surgery are two-fold: first for the patient (as for laparoscopic surgery, see Summary box 8.1) and second for the surgeon. The advantages for the surgeon include better visualisation (higher magnification) with stereoscopic views; elimination of hand tremor allowing greater precision; improved manoeuvring as a result of the ‘robotic wrist’, which in some systems allows up to seven degrees of freedom; and the fact that large external movements of the surgical hands can be scaled down and transformed to limited internal movements of the
'robotic hands', extending the surgical ability to perform complex technical tasks in a limited space. Also, the surgeon is able to work in an ergonomic environment with less stress and to achieve higher levels of concentration. The computer may also be able to compensate for the beating movement of the heart, making it unnecessary to stop the heart during cardiothoracic surgery. There may also be less need for assistance once surgery is under way.

Many surgical specialties have embraced the progression of robot-assisted techniques, including general surgery, cardiothoracic surgery, urology, orthopaedics, ear, nose and throat (ENT) surgery, gynaecology and paediatric surgery. Specialties that use microsurgical techniques also benefit from this technology. Current robotic systems were designed to offer multifunctionality including multi-anatomy and speciality capability in both operating theatre and remote environments. In the current era, however, these devices seem most often applied in pelvic surgery (typically urology, colorectal and gynaecology) within inhouse operating areas.

One major operative barrier to adoption remains the prohibitive costs for many healthcare environments. As a result the current robotic surgical market is dominated by the master–slave da Vinci system (Intuitive Surgical, MenloPark, CA, USA) (Figure 8.2), although there are several other commercially available robots and a market open to a small number of new entrants, but also a history of unsuccessful (financially

Figure 8.2 (a) The DaVinci Xi system. (b) The surgical console. (c) The robotic arms draped for a robotic coronary artery bypass grafting procedure. (d) Robotic distal coronary anastomosis.
or functionally) or withdrawn/removed devices. This is partly because of the high cost of design and development of new robot technologies and surgical instruments compatible with them, which all require design, translation and intellectual property costs. In addition to the remote master–slave platform design, direct robot systems exist and include:

- tremor suppression robots;
- active guidance systems;
- articulated mechatronic devices;
- force control systems;
- haptic feedback devices.

Each of these systems offers different advantages to the operating surgeon, ranging from reducing the need for assistants and providing better ergonomic operating positions to providing experienced guidance from surgeons not physically present in the operating theatre.

**Robotic surgery – the first 30 years**

The largest systematic overview of all robot surgical procedures from inception and covering the field’s first 30 years revealed only 99 prospective or randomised studies reporting clinical outcomes from over 28000 peer-reviewed research articles that mentioned the term ‘robotic surgery’. The 99 studies revealed data from approximately 14500 patients in trials undergoing robotic surgical procedures versus open and minimally invasive operations. The overall pooled results, regardless of specialty, revealed a decrease in blood loss and blood transfusion rate with robotic surgery when compared with both open surgery and minimally invasive surgery. Specifically, when compared with open surgery, robotic procedures demonstrated that there was a reduction in length of hospital stay and overall complication rate. However, robotic procedures did suffer from significantly longer operative times and their cost-effectiveness varied depending on operative site, technique, patient and healthcare setting. While this reveals an overall perspective from the first 30 years of robotics surgery, there remains an incumbent need to offer clearer clinical evidence regarding the most apposite operative method and technology for each individual patient.

**PREOPERATIVE EVALUATION**

**Preparation of the patient**

Although the patient may be in hospital for a shorter period, careful preoperative management is essential to minimise morbidity.

**History**

Patients must be fit for general anaesthesia and open operation if necessary. Potential coagulation disorders (e.g. associated with cirrhosis) are particularly dangerous in laparoscopic surgery. As adhesions may cause problems, previous abdominal operations or peritonitis should be documented.

**Summary box 8.3**

**Preparation for laparoscopic or robotic surgery**

- Overall fitness: cardiac arrhythmia, emphysema, medications, allergies
- Previous surgery: scars, adhesions
- Body habitus: obesity, skeletal deformity
- Normal coagulation
- Thromboprophylaxis
- Informed consent

**Examination**

Routine preoperative physical examination is required as for any major operation. Although, in general, laparoscopic/thoracoscopic surgery allows quicker recovery, it may involve longer operating times and the establishment of the pneumoperitoneum may provoke cardiac arrhythmias. Severe chronic obstructive airways disease and ischaemic heart disease may be contraindications to the laparoscopic approach. Particular attention should be paid to the presence or absence of jaundice, abdominal scars, palpable masses or tenderness. Moderate obesity does not increase operative difficulty significantly, but massive obesity may make pneumoperitoneum difficult and standard instrumentation may be too short. Access may prove difficult in very thin patients, especially those with severe kyphosis.

**Premedication**

Premedication is the responsibility of the anaesthetist, with whom coexisting medical problems should be discussed.

**Prophylaxis against thromboembolism**

Venous stasis induced by the reverse Trendelenburg position during laparoscopic surgery may be a particular risk factor for deep vein thrombosis, as is a lengthy operation and the obesity of many patients. Subcutaneous low molecular weight heparin and antithromboembolic stockings should be used routinely, in addition to pneumatic leggings during the operation. Patients already taking warfarin for other reasons should have this stopped temporarily or converted to intravenous heparin, depending on the underlying condition, as it is not safe to perform laparoscopic surgery in the presence of a significant coagulation deficit.

**Urinary catheters and nasogastric tubes**

In the early days of laparoscopic surgery, routine bladder catheterisation and nasogastric intubation were advised. Most surgeons now omit these, but it remains essential to check that the patient is fasted and has recently emptied their bladder, particularly before the blind insertion of a Verres needle. However, currently, most general surgeons prefer the direct cut-down technique into the abdomen for the introduction of the first port for the establishment of the pneumoperitoneum (Hasson technique and modified Hasson approaches). More

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recently, direct optical entry has been used, especially in the setting of bariatric surgery.

Informed consent
The basis of many complaints and much litigation in surgery, especially laparoscopic surgery, relates to the issue of informed consent. It is essential that the patient understands the nature of the procedure, the risks involved and, when appropriate, the alternatives that are available. A locally prepared explanatory booklet concerning the laparoscopic procedure to be undertaken is extremely useful.

In an elective case, a full discussion of the proposed operation should take place in the outpatient department with a surgeon of appropriate seniority, preferably the operating surgeon, before the decision is made to operate. On admission, it is the responsibility of the operating surgeon and anaesthetist to ensure that the patient has been fully counselled, although the actual witnessing of the consent form may have been delegated. The patient should understand what laparoscopic surgery involves and that there is a risk of conversion to open operation. If known, this risk should be quantified, for example the increased risk with acute cholecystitis or in the presence of extensive upper abdominal adhesions. The conversion rate will also vary with the experience and practice of the surgeon. Common complications should be mentioned, such as shoulder tip pain and minor surgical emphysema, as well as rare but serious complications, including injury to the bile ducts and visceral injury from trocar insertion or diathermy.

Preparation is very similar to that for open surgery and aims to ensure that:
- The patient is fit for the procedure.
- The patient is fully informed and has consented.
- Operative difficulty is predicted when possible.
- Appropriate theatre time and facilities are available (especially important for robotic cases).

THEATRE SET UP AND TOOLS
Operating theatre design, construction and layout are key to its smooth running on a daily basis. Originally, the video and diathermy equipment and other key tools used in laparoscopic surgery were moved around on stacks, taking up valuable floor space and cluttering up the theatre environment, which was not always ergonomic for the operating team. New theatres are designed with moveable booms that come down from the ceiling; these are easy to place and do not have long leads or wires trailing behind them (Figure 8.3). The equipment consists of at least two high-resolution liquid crystal display (LCD) monitors (and, more recently, high definition (HD) monitors for even clearer images), the laparoscopic kit for maintaining pneumoperitoneum and the audiovisual kit. The advent of DVD and other digital recording equipment has also led to these being incorporated into the rigs so that cases can be recorded with ease. This is further facilitated by cameras being inserted into the light handles of the main overhead lights so that open surgery can also be recorded without distracting the surgeons.

![Figure 8.3 Modern laparoscopic theatre set up.](image)

Image quality is vital to the success of laparoscopic surgery. New camera and lens technology allows the use of smaller cameras. Many centres now use 5-mm laparoscopes routinely. Automatic focusing and charge-coupled devices (CCDs) are used to detect different levels of brightness and adjust for the best image possible. Flat panel monitors with HD images are used to give the surgeon the best views possible and 3D technology is now being used for visualisation more routinely in some centres. The usability of the kit has also improved; touch screen panels and even voice-activated systems are now available on the market.

As minimally invasive and robotic procedures have become routine in some institutions, the dedicated theatre team for such procedures has also evolved. Surgeons and anaesthetists, as well as scrub and circulating nurses, have become familiar with working with the equipment and each other. The efficient working of the team is crucial to high-quality surgery and quick yet safe turnover. Laparoscopic tools have also changed. Disposable equipment is more readily available, which does unfortunately increase the cost of the surgery. However, easy to use, ergonomically designed and reliable surgical tools are essential for laparoscopic and robotic surgery. Simple designs for new laparoscopic ports are now being studied, with the aim of reducing the incidence of port-site hernias; see-through (optical) ports that allow the surgeon to cut down through the abdomen while observing the layers through the cameras, and new light sources within the abdomen may be simple ideas that affect surgical technique in the near future.

GENERAL INTRAOPERATIVE PRINCIPLES
Laparoscopic and thoracoscopic principles have specific principles that require careful clinical consideration. As such, they are not purely a less invasive equivalent of an open operation. For example, laparoscopic cholecystectomy is now the ‘gold standard’ for operative treatment of symptomatic gallstone disease. The main negative aspect of the technique is the increased incidence of bile duct injury compared with open cholecystectomy. Better understanding of the mechanisms of injury, coupled with proper training, will avoid most of these errors. The following sections highlight the important
technical steps that should be taken during any form of laparoscopic surgery to avoid complications.

Creating a pneumoperitoneum

There are two methods for creation of a pneumoperitoneum: open and closed.

The closed method involves blind puncture using a Verres needle. Although this method is fast and relatively safe, there is a small but significant potential for intestinal or vascular injury on introduction of the needle or first trocar.

The routine use of the open technique for creating a pneumoperitoneum avoids the morbidity related to a blind puncture. To achieve this, a 1 cm vertical or transverse incision is made at the level of the umbilicus. The umbilicus carries importance as it is a reliable anatomical landmark deriving from the embryological coalescence of the rectus sheath and peritoneum and is devoid of other myofascial planes that could complicate subsequent entry into the peritoneum. Two small retractors are used to dissect bluntly the subcutaneous fat and expose the midline fascia. Two sutures are inserted each side of the midline incision (into the rectus sheath confluence), followed by the creation of a 1 cm opening in the fascia. Free penetration into the abdominal cavity is confirmed by the gentle introduction of a finger. Finally, a Hasson trocar (or other blunt-tip trocar) is inserted and anchored with the fascial sutures (Figure 8.4). This is considered the Hasson or ‘modified Hasson’ approach. The term ‘modified’ is used here to denote the same principle as the original Hasson with the midline exposure and access, except that the exact technique has been changed to suit an individual surgeon, such as the adoption of a particular angle of retraction of the umbilicus before an incision into the midline is made to get access to the peritoneum.

Rarely, a third, or combination, approach may be employed. Here an open technique is followed with a smaller than usual midline incision. Once access to the peritoneum is visualised, a Verres needle is inserted under direct vision, and then insufflation is carried out. This small open approach then allows the introduction of a laparoscopic port with a view to reducing trauma of the pneumoperitoneum. Such an approach may have benefits for complex cases, such as those for ‘re-do’ procedures, where the risk of umbilical adhesions during pneumoperitoneum may be high.

The open technique may initially appear time consuming and even cumbersome; however, with practice, it is quick, efficient and safe overall. Optical entry to the abdomen under direct vision using optical ports (especially in bariatric surgery) is gaining favour with many laparoscopic surgeons. This allows quick and safe entry to the peritoneal cavity using bladeless see-through trocars that allow the different layers to be dissected through using the laparoscope within an optical port to be inserted into the abdomen.

Preoperative problems

Previous abdominal surgery

Previous abdominal surgery is no longer a contraindication to laparoscopic surgery, but preoperative evaluation is necessary to assess the type and location of surgical scars. As mentioned earlier, the open technique for insertion of the first trocar is safer. Before trocar insertion, the introduction of a finger-tip helps to ascertain penetration into the peritoneal cavity and also allows adhesions to be gently removed from the entry site. After the tip of the cannula has been introduced, a laparoscope is used as a blunt dissector to tease adhesions gently away and form a tunnel towards the quadrant where the operation is to take place. This step is accomplished by a careful pushing and twisting motion under direct vision. With experience, the surgeon learns to differentiate visually between thick adhesions that may contain bowel and should be avoided and thin adhesions that would lead to a window into a free area of the peritoneal cavity.

Obesity

Laparoscopic and robotic surgery has proved to be safe and effective in the obese population. In fact, some procedures are less difficult than their open counterparts for the morbidly obese patient, e.g. in bariatric surgery. Technical difficulties occur, however, in obtaining pneumoperitoneum, reaching the operative region adequately and achieving adequate exposure in the presence of an obese colon. Increased thickness of the subcutaneous fat makes insufflation of the abdominal cavity more difficult. With the closed technique, a larger Verres needle is often required for morbidly obese patients. Pulling the skin up for fixation of the soft tissues is better accomplished with towel clamps. Only moderate force should be used, to avoid separating the skin farther from the fascia. The needle should be passed at nearly a right angle to the skin and preferably above the umbilicus, where the peritoneum is more firmly fixed to the midline. The open technique of inserting a Hasson trocar is easier and safer for obese patients, but technically demanding in morbidly obese patients, where optical entry is now more commonplace. The main difficulty is reaching the fascia. A larger skin incision (1–3 cm), starting at the umbilicus and extending superiorly, may facilitate this. To reach the operative area adequately, the location of some of the ports has to be modified and, in some instances, larger and

Figure 8.4 Open technique with Hasson port. Apply safe principles of closed technique.
longer instruments are necessary. When the length of the laparoscope appears to be insufficient to reach the operative area adequately, the initial midline port should be placed nearer to the operative field. Recently, the use of optical port entry for laparoscopic bariatric surgery has revolutionised port entry for morbid obesity cases.

Operative problems

Intraoperative perforation of a viscus
Perforation of any viscus, such as bowel, solid organs and blood vessels (including the aorta), is a potential hazard of using the laparoscopic approach and these complications may be minimised with surgical experience, education, preparation and patient selection. One example, in a common laparoscopic procedure such as cholecystectomy, includes perforation of the gallbladder. This is more common with the laparoscopic technique than with the open technique (see also Chapter 67). Some authors have reported an incidence of up to 30%, but it does not appear to be a factor in increasing the early postoperative morbidity. However, it is well known that bile is not a sterile fluid and bacteria can be present in the absence of cholecystitis. Unless the perforation is small, closure with endoloops or endoclips should be attempted to avoid contamination prior to extraction, which should be with the use of an endobag. Bilious leakage should be suctioned and washed out. If there is stone spillage, every attempt must be made to collect and extract the stones, and if there is a possibility of stones being retained in the peritoneum, then an ultrasound should be arranged 6 weeks postoperatively to assess a collection around a stone and the patient should be informed of this outcome postoperatively.

Antibiotics to manage known sepsis or septicemia in a patient undergoing surgery
Operating on a patient with established septicemia or sepsis is not typically recommended unless the operation will contribute to removing or minimising infectious origins. Where necessary pre-, peri- and postoperative antibiotics should be administered, in accordance with local microbiological advice.

Antibiotics to prevent infections and sepsis
A single dose of antibiotics should be administered within 1 hour of skin incision; in contaminated, semi-contaminated or complex procedures, additional doses should be administered, based on local microbiological advice.

Bleeding
In some of the larger series, bleeding has been the most common cause of conversion to an open procedure. Bleeding plays a more important role in laparoscopic surgery because of factors inherent to the technique. These include a limited field that can easily be obscured by relatively small amounts of blood, magnification that makes small arterial bleeding appear to be a significant haemorrhage and light absorption that obscures the visual field.

HOW TO AVOID BLEEDING
As in any surgical procedure, the best way to handle intraoperative bleeding is to prevent it from happening. This can usually be accomplished by identifying patients at high risk of bleeding, having a clear understanding of the laparoscopic anatomy and employing careful surgical technique.

Risk factors that predispose to increased bleeding include:
- cirrhosis;
- inflammatory conditions (acute cholecystitis, diverticulitis);
- patients on clopidogrel and or dipyridamole;
- coagulation defects: these are contraindications to a laparoscopic procedure.

BLEEDING FROM A MAJOR VESSEL
Damage to a large vessel requires immediate assessment of the magnitude and type of bleeding. When the bleeding vessel is identified, a fine-tip grasper can be used to grasp it and apply either electrocautery or a clip, depending on its size. When the vessel is not identified early and a pool of blood forms, compression should be applied immediately with a blunt instrument, a cotton swab (ENT or mastoid swab) or with the adjacent organ. Good suction and irrigation are of utmost importance. Once the area has been cleaned, pressure should be released gradually to identify the site of bleeding. Insertion of an extra port may be required to achieve adequate exposure and at the same time to enable the concomitant use of a suction device and an insulated grasping grasper. Although most bleeding vessels can be controlled laparoscopically, judgement should be used in deciding when not to prolong bleeding, but to convert to an open procedure at an early stage. Surgicel® (absorbable fibrillar oxidized cellulose polymer) or other clot-promoting strips, tissue glues or other haemostatic agent may also be used laparoscopically to aid haemostasis. If at any stage bleeding is difficult to stem laparoscopically, there should be no delay in converting to an open procedure in the interests of patient safety.

BLEEDING FROM ORGANS ENCOUNTERED DURING SURGERY
Intraoperative bleeding from organs can usually be prevented by performing the dissection in the correct plane. As previously mentioned, the common laparoscopic example of a cholecystectomy requires understanding the management of bleeding from the gallbladder bed. When a bleeding site appears during detachment of the gallbladder, the dissection should be carried a little farther to expose the bleeding point adequately. Once this step has been performed, direct application of electrocautery usually controls the bleeding. If bleeding persists, indirect application of electrocautery is useful because it avoids detachment of the formed crust. This procedure is accomplished by applying pressure to the bleeding point with a blunt, insulated grasping grasper and then applying electrocoagulation by touching this grasper with a second insulated grasper that is connected to the electrocautery device. One must be careful to keep all conducting surfaces of the grasping within the visual field while applying the electrocautery current.
BLEEDING FROM A TROCAR SITE

Bleeding from the trocar sites is usually controlled by applying upwards and lateral pressure with the trocar itself. Considerable bleeding may occur if the falciform ligament is impaled with the substernal trocar or if one of the epigastric vessels is injured. If significant continuous bleeding from the falciform ligament occurs, haemostasis is achieved by percutaneously inserting a large, straight needle at one side of the ligament. A monofilament suture attached to the needle is passed into the abdominal cavity and the needle is exited at the other side of the ligament using a grasper (Figure 8.5). The loop is suspended and compression is achieved. Maintaining compression throughout the procedure usually suffices. After the procedure has been completed, the loop is removed under direct laparoscopic visualisation to ensure complete haemostasis. When significant continuous bleeding from the abdominal wall occurs, haemostasis can be accomplished either by pressure or by suturing the bleeding site. Pressure can be applied using a Foley balloon catheter. The catheter is introduced into the abdominal cavity through the bleeding trocar site wound, the balloon is inflated and traction is placed on the catheter, which is bolstered in place to keep it under tension. The catheter is left in situ for 24 hours and then removed. Although this method is successful in achieving haemostasis, the authors favour direct suturing of the bleeding vessel. This manoeuvre is accomplished by extending the skin incision by 3 mm at both ends of the bleeding trocar site wound. Two figure-of-eight sutures are placed in the path of the vessel at both ends of the wound. Devices such as the EndoClose may also be used to apply transabdominal sutures under direct laparoscopic view to close port sites that bleed.

EVACUATION OF BLOOD CLOTS

The best way of dealing with blood clots is to avoid them. As mentioned, careful dissection and identification of the cystic artery and its branches, as well as identifying and carrying out dissection of the gallbladder in the correct plane, help to prevent bleeding from the cystic vessels and the hepatic bed. Nevertheless, clot formation takes place when unsuspected bleeding occurs or when inflammation is severe and a clear plane is not present between the gallbladder and the hepatic bed. The routine use of 5000–7000 units of heparin per litre of irrigation fluid helps to avoid the formation of clots. When extra bleeding is foreseen, a small pool of irrigation fluid can be kept in the operative field to prevent clot formation. After clots have formed, a large bore suction device should be used for their retrieval. Care should be taken to avoid suctioning in proximity to placed clips.

Principles of electrosurgery during laparoscopic surgery

Electrosurgical injuries during laparoscopy are potentially serious. The vast majority occur following the use of monopolar diathermy. The overall incidence is between one and two cases per 1000 operations. Electrical injuries are usually recognised at the time that they occur, with patients commonly presenting 3–7 days after injury with complaints of fever and abdominal pain. As these injuries usually present late, the reasons for their occurrence are largely speculative. The main theories are: (1) inadvertent touching or grasping of tissue during current application; (2) direct coupling between a portion of bowel and a metal instrument that is touching the activated probe (Figure 8.6); (3) insulation breaks in the electrodes; (4) direct sparking to bowel from the diathermy probe; and (5) current passage to the bowel from recently coagulated, electrically isolated tissue. Bipolar diathermy is safer and should be used in preference to monopolar diathermy, especially in anatomically crowded areas. If monopolar diathermy is to be used, important safety measures include attainment of a perfect visual image, avoiding excessive current application and meticulous attention to insulation. Alternative methods of performing dissection, such as the use of ultrasonic devices, may improve safety.

POSTOPERATIVE CARE

The postoperative care of patients after laparoscopic surgery is generally straightforward, with a low incidence of pain or other problems. The most common routine postoperative symptoms are a dull upper abdominal pain, nausea and pain...
around the shoulders (referred from the diaphragm). There has been some suggestion that the instillation of local anaesthetic to the operating site and into the suprarepatic space, or even leaving 1 litre of normal saline in the peritoneum, serves to decrease postoperative pain. It is a good general rule that if the patient develops a fever or tachycardia, or complains of severe pain at the operation site, something is wrong and close observation is necessary. In this case, routine investigation should include a full blood count, C reactive protein (CRP) measurement, liver function tests, an amylase test and, probably, an ultrasound scan of the upper abdomen to detect fluid collections. If bile duct leakage is suspected, endoscopic retrograde cholangiopancreatography (ERCP) may be needed. If in doubt, relaparoscopy or laparotomy should be performed earlier rather than later. Death following technical errors in laparoscopic cholecystectomy has often been associated with a long delay in deciding to re-explore the abdomen.

In the absence of problems, patients should be fit for discharge within 24 hours. They should be given instructions to telephone the unit or their general practitioner and to return to the hospital if they are not making satisfactory progress.

Nausea
About half of patients experience some degree of nausea after laparoscopic surgery and, rarely, this may be severe. It usually responds to an antiemetic, such as ondansetron, and settles within 12–24 hours. It is made worse by opiate analgesics and should be avoided.

Shoulder tip pain
The patient should be warned about this preoperatively and told that the pain is referred from the diaphragm and not due to a local problem in the shoulders. It can be at its worst 24 hours after the operation. It usually settles within 2–3 days and is relieved by simple analgesics, such as paracetamol.

Abdominal pain
Pain in one or other of the port site wounds is not uncommon and is worse if there is haematoma formation. It usually settles very rapidly. Increasing pain after 2–3 days may be a sign of infection and, with concomitant signs, antibiotic therapy is occasionally required. Occasionally, herniation around the port may account for localised pain and this can sometimes be due to a Richter’s hernia, such that the patient exhibits no sign of intestinal obstruction. Successful laparoscopic surgery should not cause a patient increasing or undue pain. If there are any clinical concerns postoperatively due to worsening pain, tachycardia and or pyrexia, senior review with a view to imaging, or increasingly commonly relaparoscopy, should be considered.

Analgesia
A 100-mg diclofenac suppository may be given at the time of the operation (if this medication is not contraindicated). It is important that the patient provides separate consent for this if the suppository is to be administered peroperatively. Suppositories may be administered a further two or three times postoperatively for relief of more severe pain. Otherwise, 500–1000 mg of paracetamol 4-hourly usually suffices (orally or, if more pain, intravenously). Opiate analgesics cause nausea and should be avoided unless the pain is very severe. In this case, suspect a postoperative complication (as above). The majority of patients require between one and four doses of 1 g of paracetamol postoperatively. Severe pain after routine laparoscopic cases should warn the clinician that there may be an iatrogenic or surgical cause of this pain that may need further investigation with blood tests, imaging and even relaparoscopy.

Orogastric tube
An orogastric tube may be placed during the operation if the stomach is distended and obscuring the view. It is not necessary in all cases. It should be removed as soon as the operation is over and before the patient regains consciousness. This is more routinely used in bariatrics and oesophagogastric surgery, where a larger (32F or 34F) tube is used.

Oral fluids
There is no significant ileus after laparoscopic surgery, except in resectional procedures, such as colectomy or small bowel resection. Patients can start taking oral fluids as soon as they are conscious; they usually do so 4–6 hours after the end of the operation.

Oral feeding
Provided that the patient has an appetite, a light meal can be taken 4–6 hours after the operation. Some patients remain slightly nauseated at this stage, but almost all eat a normal breakfast on the morning after the operation.

Patients will require advice about what they can eat at home. They should be told that they can eat a normal diet but should avoid excess. It seems sensible to avoid high-fat meals for the first week, although there is no clear evidence that this is necessary.

Urinary catheter
This depends on the operation. If a urinary catheter has been placed in the bladder during an operation with likely short stay, it should be removed before the patient regains consciousness if the procedure has proceeded well. The patient should be warned of the possibility and symptoms of postoperative cystitis and told to ask advice in the unlikely event of this occurring.

Drains
The use of postoperative drains in laparoscopy patients depends on the operation performed. Drains are used to assess postoperative blood loss if this is a clinical concern or to assess the nature of intraperitoneal fluids, depending on procedure...
and postoperative monitoring needs. Some surgeons drain the abdomen at the end of laparoscopic cholecystectomy, although this is controversial. If a drain is placed to vent the remaining gas and peritoneal fluid, it should be removed within 1 hour of the operation. If it has been placed because of excessive hepatic bleeding or bile leakage it should be removed when that problem has resolved, usually after 12–24 hours. Continued blood loss from a drain is an indication for re-exploration of the abdomen.

### DISCHARGE FROM HOSPITAL

Patient discharge is based on clinical indicators and their fitness for recuperating in a non-hospital environment. One of the core drivers for the application of minimally invasive surgery is an earlier recovery and therefore discharge from hospital. For the common laparoscopic procedure of cholecystectomy, most surgeons discharge a significant proportion of their laparoscopic cholecystectomy patients on the day of surgery, but some are kept in overnight and discharged the following morning. Patients should not be discharged until they are seen to be comfortable, have passed urine and are eating and drinking satisfactorily. They should be told that if they develop abdominal pain or other severe symptoms they should return to the hospital or to their general practitioner. Even for more major cases, including procedures such as laparoscopic anterior resection, some units have demonstrated a safe and feasible protocol for a 24-hour stay.

### Skin sutures

If non-absorbable sutures or skin staples have been used, they can be removed from the port sites after 7 days.

### Mobility and convalescence

Patients can get out of bed to go to the toilet as soon as they have recovered from the anaesthetic and they should be encouraged to do so. Such movements are remarkably pain free when compared with the mobility achieved after an open operation. Similarly, patients can cough actively and clear bronchial secretions, and this helps to diminish the incidence of chest infections. Many patients are able to walk out of hospital on the evening of their operation and almost all are fully mobile by the following morning. Thereafter, the postoperative recovery is variable. Some patients prefer to take things quietly for the first 2–3 days, interspersing increasing exercise with rest. After the third day, patients will have undertaken increasing amounts of activity. The average return to work is about 10 days.

## THE PRINCIPLES OF COMMON LAPAROSCOPIC PROCEDURES

The principles of common laparoscopic procedures are described in the appropriate chapters:

- laparoscopic cholecystectomy (Chapter 67);
- laparoscopic inguinal hernia repair (Chapter 60);
- laparoscopic antireflux surgery (Chapter 63);
- laparoscopic appendicectomy (Chapter 72);
- laparoscopic bariatric surgery (Chapter 64);
- laparoscopic colectomy/anterior resection (Chapters 70 and 73);
- laparoscopic upper gastrointestinal (GI) surgery (Chapters 62, 63 and 69)

Other elective minimally invasive (laparoscopic, thoracoscopic) or robotic procedures that are now widely utilised in certain specialist centres include:

- colectomy;
- gastrectomy;
- splenectomy;
- nephrectomy;
- adrenalectomy;
- prostatectomy (typically robotic);
- thyroid and parathyroid surgery;
- aortic aneurysm surgery;
- single-vessel coronary artery bypass surgery;
- video-assisted thoracoscopic surgery (VATS);
- laparoscopic hernia surgery (inguinal, femoral, paraumbilical, incisional).

Laparoscopy has also been used in certain emergency situations (in stable patients) in the hands of experienced laparoscopic surgeons. These include laparoscopic appendicectomy (typically the most common minimally invasive emergency procedure), repair of a perforated duodenal ulcer, laparoscopic cholecystectomy in severe cholecystitis (so-called ‘hot’ cholecystectomies), and treatment of intestinal obstruction secondary to adhesions, strangulated hernia repairs and, also, the laparoscopic evaluation of stable trauma patients.

Procedures that have been carried out using robotically assisted minimally invasive surgery include all of those listed above. Currently, robotic surgery still has certain disadvantages:

- increased cost;
- increased set up of the system and operating time;
- socioeconomic implications;
- significant risk of conversion to conventional techniques;
- prolonged learning curve;
- multiple repositioning of the arms can cause trauma;
- haemostasis;
- collision of the robotic arms in extreme positions.
Until these are overcome, by continued development of the technology and the drive of surgeons to progress in the field, robotically assisted surgery will not be commonplace. However, the potential for such systems is immense and continued research and clinical trials will pave the way for future generations of surgeons and patients alike.

FURTHER DEVELOPMENTS THAT HAVE MADE MINIMALLY INVASIVE SURGERY EVEN LESS INVASIVE

Single incision laparoscopic surgery

Laparoscopy has reduced the trauma from surgery, compared with open techniques, and is now used routinely for benign and oncological surgery in many centres. However, there is continued work on how to reduce the trauma and scarring from the incisions used in laparoscopic surgery because multiple port sites are needed for most procedures. Natural orifice transluminal endoscopic surgery (NOTES) (see below) addresses this but, at present, the safety of the transgastric route is not sufficient for the routine use of this approach to surgery. Advanced laparoscopists have therefore turned to focussing on the single incision for open entry via the umbilicus as an alternative. Single incision laparoscopic surgery (SILS) is a technique adopted by some surgeons to insert all the instrumentation via a single incision, through a multiple channel port via the umbilicus, to carry out the procedure. The benefit is that only one incision, through a natural scar (the umbilicus), is made, therefore these procedures are virtually 'scarless'. Second, the use of fewer port sites around the abdomen gives the potential for less pain, less risk of port site bleeding and reduced incidence of port site hernia. This technique has many other synonyms, including laparoscopendous single port endoscopy (LESS) and single port access (SPA) surgery among many others, although SILS has gained the most recognition. It does require specially manufactured multichannel ports and often rotulating instruments. There has been an explosion of activity in SILS procedures in the last few years and, in some units, laparoscopic cholecystectomies and hernias are routinely started as SILS cases. The clinical benefit and cost-effectiveness of this technique, which has a difficult learning curve and specific instrument requirements, remain under review, although it has been adopted as a routine approach for some procedures in some units. Early evidence understandably demonstrated better cosmetic outcomes and less pain in the immediate postoperative period; however, this needs to be further corroborated with higher levels of evidence with longer-term follow-up results. Specifically, because the SILS approach was not designed for improving clinical outcomes when compared with standard minimally invasive approaches, any improvements in pain and cosmesis between SILS and standard minimally invasive approaches require further elucidation.

Natural orifice transluminal endoscopic surgery (NOTES)

This technique, whereby surgeons enter the peritoneal cavity via endoscopic puncture of a hollow viscus, has been much publicised in recent years. The NOTES approach has been utilised in nearly every body system and operative specialty addressing the pelvis, abdomen and thorax. Worldwide adoption rates compared to standard open and minimally invasive approaches remain very low. Transvaginal NOTES cholecystectomies have been performed in humans successfully, although hybrid procedures (joint laparoscopy and NOTES) are still employed regularly for safety reasons. The closure of the visceral puncture site is the issue that has prevented widespread uptake of this technique, as transgastric and transcolonic closure of peritoneal entry sites in a routinely safe way remains unperfected for general use. Also, the equipment needed has significant cost and training needs (including surgeons and a large variety of ancillary team members that range from scrub nurses to anaesthetists) and requires a large number of practitioners in the team at present. Nevertheless, it has much promise to be a technique for truly scarless surgery in the future and much research continues in this field, which is less widely adopted at present than SILS.

THE FUTURE

Although there is no doubt that minimal access surgery has changed the practice of surgeons, it has not changed the nature of disease. The basic principles of good surgery still apply, including appropriate case selection, excellent exposure, adequate retraction and a high level of technical expertise. If a procedure makes no sense with conventional access, it will make no sense with a laparoscopic approach. Laparoscopic and robotic surgery training is key to allow the specialty to progress. The pioneers of yesterday have to teach the surgeons of tomorrow not only the technical and dextrous skills required, but also the decision-making and innovative skills necessary for the field to continue to evolve. Training is often perceived as difficult, as trainees have less control over the trainees at the time of surgery and caseloads may be smaller, especially in centres where laparoscopic and robotic procedures are not common. However, trainees now rightly expect exposure to these procedures, and training systems should be adaptable for international exposure so that these techniques can be disseminated worldwide. The predominant video and digital component of these new techniques opens the door for simulation approaches for training in these modalities, which has demonstrated benefits in reducing learning curves and in turn is aimed at improving patient outcomes. The ultimate goal for this educational approach is to develop expert surgeons through the ‘totally safe’ and ‘risk free’ environment of simulation before they actually have to operate on patients. The current status for laparoscopic trainees reflects their decreased experience in open approaches so that they feel less comfortable converting cases such as laparoscopic cholecystectomies to open cases. It is important that the ‘straight to minimally invasive’ trainees continue to have
training in open skills so that they can apply both approaches where necessary.

Improvements in instrumentation, the continued progress of robotic surgery and the development of structured training programmes are key to the future of minimal access surgery. The use of robots in surgery has increased dramatically in the last decade. Indeed, robots are now available not only for assisting in surgery, but also for aiding in the perioperative management of surgical patients. The remote presence systems (In Touch Health, Santa Barbara, CA, USA) allow clinicians to assess patients in real time and interact with them while they are not on site or even on a different continent. Applying established devices in different contexts also offers the introduction of innovation; for example, the LABEL procedure (Laser Assisted Bile duct Exploration by Laparoendoscopy for choledocholithiasis) was developed when the concept of laser stone management in urology was applied to laparoscopic biliary tree surgery. Continued advances in related technologies, such as computer science, will allow the incorporation of augmented reality systems alongside robotic systems to enhance surgical precision in image-guided surgery. Endoluminal robotic surgery remains in its infancy, but systems are being developed that will enable navigation within the colon to allow surgery on lesions in spaces that are accessible from the outside without an exterior incision being made. The advent of nanotechnology should also bring about much change in surgery. Miniaturisation may be possible, potentially allowing surgery at a cellular level to be carried out.

At present, work has already started on single-port laparoscopy (see above under Single incision laparoscopic surgery), in which a single port may act as a camera and have unfolding instruments that open up once they are inside the peritoneum to perform the surgery, therefore reducing the number of ports needed. Extensive research is also being carried out in the field of NOTES. Minimising the potential contamination of the peritoneum and the ability to carry out a safe closure of the peritoneal entry site are the main technical challenges of this type of minimally invasive and essentially ‘scarless’ or ‘incisionless’ surgery. It is certain that there is much that is new in minimal access surgery. Only time will tell how much of what is new is truly better.

Specifically, the future evolution of robotic systems includes full integration with next generation technologies such as advanced augmented reality, autobionics, neuromorphic visual processing and real-time diagnostics and theranostics, exemplified by the i-Knife (real-time tissue metabolic profiling and tissue-level diagnosis, developed by Zoltan Takats at Imperial College London). Large master–slave constructions with multiple arms are likely to give way to flexible access bio-inspired (FAB) systems. These will probably offer full robotic arm articulation in much more portable devices with low energy needs. They would be totally modular with integrated imaging and would have platforms to offer multi-purpose usage to increase utilisation and cost efficiency. These systems would also result in a smaller physical footprint, with cheaper devices offering more utility, precision and dexterity on platforms that allow both master–slave and direct functionality.

One major obstacle in minimally invasive technology includes the ‘Achilles heel’ of cost efficiency and device financing in an increasingly rationed global healthcare environment; this is an issue which will require surgical liaison with hospital management and national policy providers. Surgeons need to continue to have a dialogue, discussing their experiences and ideas regarding all the minimally invasive approaches. None of these techniques needs to exist in isolation. The future can offer hybridisation of these approaches, including a vast array of possibilities such as Robotic-SILS, Robotic-NOTES or even endoscopic NOTES-augmented SILS (endoscopes passed through a SILS port). Such cross-fertilisation can offer new innovation and techniques; thus, harvesting the advantages of newer procedures and discarding the individual weaknesses of others can ultimately improve patient outcomes and results.

The cleaner and gentler the act of operation, the less the patient suffers, the smoother and quicker his convalescence, the more exquisite his healed wound.

Berkeley George Andrew Moynihan (1920)

FURTHER READING