Basrah Journal Of Surgery

Review Article

Bas J Surg, March, 19, 2013

LAPAROSCOPIC ENTRY: A REVIEW OF TECHNIQUES, TECHNOLOGIES, AND COMPLICATIONS

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Introduction

Laparoscopy (Gr: Laparo-abdomen, scopein-to examine) is the art of examining the abdominal cavity and its contents. It requires insertion of a cannula through the abdominal wall, distention of the abdominal cavity with gas or air (pneumoperitoneum), and visualization and examination of the abdomen's contents with an illuminated telescope. With the advent of videocameras and other ancillary instruments, laparoscopy rapidly advanced from a being a diagnostic procedure to one used in fallopian tubal occlusion for sterilization and eventually in the performance of numerous surgical procedures in all surgical disciplines for a variety of indications.

A minimally invasive procedure has many advantages for patients, health care systems, and society at large. A meta-analysis of 27 randomized controlled trials (RCTs) compared laparoscopy and laparotomy for benign gynaecological procedures[1]. The authors concluded that the risk of minor complications after gynaecological surgery is 40% lower with laparoscopy than with laparotomy, although the risks of major complications are similar. The overall risk for any complication is 8.9% with laparoscopy, compared with 15.2% with laparotomy (relative risk [RR] 0.6; 95% confidence interval [CI] 0.5–0.7). There is no difference between laparoscopy and laparotomy in the risk of major complications (1.4% in each group, RR 1.0; 95% CI 0.6–1.7), but minor complications were significantly less frequent with laparoscopy (7.5% vs. 13.8%, RR 0.6; 95% CI 0.5–0.7)[1].

A Cochrane review of trials involving 324 patients concluded that laparoscopic surgery for benign ovarian tumours is associated with reduced risk of any adverse effect of surgery, reduced pain, and fewer days in hospital compared with laparotomy. There was no difference between the procedures with regard postoperative infections and tumour recurrence[2].

Access into the abdomen is the one challenge of laparoscopy that is particular to the insertion of surgical instruments through small incisions. Access is therefore associated with injuries to the gastrointestinal tract and major blood vessels, and at least 50% of these major complications occur prior to commencement of the intended surgery[3]. This complication rate has remained the same during the last 25 years. The majority of injuries are due to the insertion of the primary umbilical trocar[4]. Increased morbidity and mortality result when laparoscopists or patients do not recognize injuries early or do not address them quickly[4].

To minimize entry-related injuries, several techniques, instruments, and approaches have been introduced during the last century. These include the Veress-pneumoperitoneum-trocar, "classic" or closed entry[5], the open (Hasson) technique[6], direct trocar insertion without prior pneumoperitoneum[7], use of shielded disposable trocars[8], optical Veress needle[9], optical trocars[10], radially expanding trocars[11] and a trocarless reusable, visual access cannula[12]. Each of these methods of entry enjoys a certain degree of popularity according to the surgeon's training, experience, and bias, and according to regional and interdisciplinary variability.

Closed entry (classic) laparoscopy Historical

The classic, or closed entry, laparoscopic technique requires cutting of the abdominal skin with a scalpel, insufflation of air or gas into the abdomen (establishment of pneumoperitoneum), and insertion of a sharp trocar/cannula system into the abdomen. Following removal of the sharp trocar, the abdominal cavity is examined by an illuminated telescope through the cannula.

The first laparoscopy in a human was performed by Jacobeus of Sweden in 1910[13]. In Canada, laparoscopy was introduced by Dr Victor Gomel, University of British Columbia, Dr Jacques Rioux, Laval University, Quebec, and Dr Albert Yuzpe, University of Western Ontario, in 1970[14].

Establishment of pneumoperitoneum, The veress needle

In 1947, Raoul Palmer of France popularized the use of the Veress needle using CO_2 to induce pneumoperitoneum for laparoscopy, and he subsequently published on its safety in the first 250 patients[5]. Palmer emphasized that the creation of pneumoperitoneum remains a vital first step, and it is one still associated with recognized complications.

Several surveys indicate that most gynaecologists practising laparoscopy worldwide use the Veress needle-pneumoperitoneum-primary trocar technique to access the abdomen[15–18]. In a Canadian survey of 407 (51% responding) obstetricians and gynaecologists, 96.3% reported always inducing pneumoperitoneum prior to insertion of the primary trocar, 1.2% sometimes, and 2% never (0.5% made no response)[7]. Furthermore, 26.4% of respondents had experienced vessel or organ injury attributable to the Veress needle, and 25.6% and 15.0% experienced vessel or organ injury from the primary and secondary trocars, respectively[15].

Veress Needle Insertion Sites

Under usual circumstances, the Veress needle is inserted in the umbilical area, in the midsagittal plane, with or without stabilizing or lifting the anterior abdominal wall. In patients known or suspected to have periumbilical adhesions, or after failure to establish pneumoperitoneum after three attempts, alternative sites for Veress needle insertion may be sought[19–21].

Left upper quadrant (LUQ, Palmer's point) CO_2 insufflation.

In patients with previous laparotomy, Palmer advocated insertion of the Veress needle 3 cm below the left subcostal border in the midclavicular line[3]. This technique should be considered in the obese as well as the very thin patient. In very thin patients, especially those with a prominent sacral promontory and android pelvis, the great vessels lie 1 cm to 2 cm underneath the umbilicus[22-23] and in obese women, the umbilicus is shifted caudally to the aortic bifurcation[24]. LUQ insufflation requires emptying of the stomach by nasogastric suction and introduction of the Veress needle perpendicularly to the skin. Patients with previous splenic or gastric surgery, significant hepatosplenomegaly, portal hypertension, or gastropancreatic masses should be excluded[25]. There is significantly more subcutaneous fat at the umbilical area than at the LUQ insertion site. After establishment of the pneumoperitoneum, trocars of various diameters and shapes may be introduced at the same site as the Veress, followed by additional trocar/cannula systems inserted under direct vision, as required[26–29].

Transuterine Veress CO_2 insufflation

Using a long Veress needle, pneumoperitoneum has been established through the fundus of the uterus transvaginally[30-35]. This technique has been especially helpful in the obese women[32-35]. In one study of 138 women weighing 250 lbs to 400 lbs, failure to establish pneumoperitoneum occurred in 13.8% (5/36) through the umbilicus, in 3.6% (3/83) through the uterus, in 8.3% (1/12) subcostally, and in 28.6% (2/7) through the open (Hasson) technique[34]. A prospective randomized study compared the conventional infraumbilical route with a transuterine route in 100 overweight and obese women (BMI>25kg/m2) in establishing pneumoperitoneum[35]. In the infraumbilical group, pneumoperitoneum was achieved at a ratio (punctures/ pneumoperitoneum) of 56/49 (1.14) with one failure, but in the transuterine group the ratio was 53/51 (1.04)[35].

Trans cul-de-sac CO2 insufflation

The posterior vaginal fornix has been reported as another site through which to establish pneumoperitoneum, especially in obese women[36].

Ninth or tenth intercostal space CO2 insufflation

Since the parietal peritoneum is adhered to the under-surface of the ribs at the costal margin, some gynaecologists insert the Veress needle through the ninth or tenth intercostal space[37]. The inclusion and exclusion criteria are the same as per LUQ insertion. The Veress needle is inserted directly through the intercostal space at the anterior axillary line along the superior surface of the lower rib to avoid injury to the underlying neurovascular bundle.

Following pneumoperitoneum, established at 20 to 25 mm Hg pressure, 5 mm laparoscopes are introduced at Palmer's point for inspection, followed by additional trocars, inserted under direct vision, to facilitate the required surgery and/or perform adhesiolysis when indicated.

A retrospective review of 918 insufflations through the ninth intercostal space found one entry into the stomach and one into the pleural space (causing a pneumothorax) by the Veress needle[38].

Challenges

Anterior abdominal wall adhesions

Adhesions at the umbilical area are found in approximately 10% of all laparoscopies[39]. One series of 4532 laparoscopies reported an incidence of only 0.2 per 1000[40]. In women with no previous abdominal surgery, umbilical adhesions are found in 0% to 0.68% of laparoscopies. Rates of umbilical adhesions range from 0% to 15% in women with prior laparoscopic surgery, from 20% to 28% in those who have had previous laparotomy with horizontal suprapubic incision, and from 50% to 60% in those who have had previous laparotomy with longitudinal incision[38,39,41,42]. Patients with midline incisions performed for gynaecologic indications had significantly more adhesions (109/259, 42%) than those with all types of incisions performed for obstetric indications (12/55, 22%)[42].

In some research protocols, preoperative ultrasonography to detect anterior wall adhesions has been found to be useful, but it needs further evaluation, and there is insufficient evidence to recommend routine preoperative ultrasound[43,44]. In 58 of 69 subjects, laparoscopic or laparotomy findings confirmed the ultrasound findings of "restricted visceral slide" in the presence of visceral adhesions[43].

Angle of Veress needle insertion

Hurd et al. reported on computerized axial tomography (CT) scans of 38 unanaesthetized women of reproductive age. The position of the umbilicus was found, on average, 0.4 cm, 2.4 cm, and 2.9 cm caudally to the aortic bifurcation in normal weight (BMI<25kg/m2), overweight (BMI25–30 kg/m^2), and obese (BMI>30 kg/m2) women, respectively. In all cases, the umbilicus was cephalad to where the left common iliac vein crossed the midline at the sacral promontory[38]. Therefore, the angle of the Veress needle insertion should vary accordingly from

45° in non-obese women to 90° in very obese women[24].

Veress needle safety tests or checks

Several studies have described tests and techniques for determining the correct placement of the Veress needle. These include the double click sound of the Veress needle, the aspiration test, the hanging drop of saline test[45], the "hiss" sound test[46], and the syringe test[19,47,48]. Although all these tests and techniques may be helpful in accessing the peritoneal cavity, the fact that visceral and vascular injuries occur shows that they are not foolproof. In fact, a recent prospective study reported that the double click, aspiration, and hanging drop tests provided very little useful information on the placement of the Veress needle[49]. In view of recent evidence, failure to perform these tests should no longer be considered as substandard care or negligence[49].

Some surgeons waggle the Veress needle from side to side, believing that this shakes an attached organ from the tip of the needle and confirms correct intra-abdominal placement. However, this manoeuvre can enlarge a 1.6 mm puncture injury to an injury of up to 1 cm in viscera or blood vessels[50].

Elevation of the anterior abdominal wall

Many surgeons advocate elevating the lower anterior abdominal wall by hand or using towel clips at the time of Veress or primary trocar insertion[51]. One study used a suprapubic port to compare the efficacy of manual elevation below the umbilicus and of towel clips placed within and 2 cm from the umbilicus[51]. They reported that only towel clips provided significant elevation of peritoneum (mean 6.8 cm above the viscera) that was maintained during the force of the primary trocar insertion[51]. Using this technique, however, one surgeon caused aortic injury to two patients in one month[52].

Hill and Maher reported 26 (4.8%) omental perforations as the omentum was elevated (lifted by hand), together with the anterior wall, during 542 direct trocar insertions for lap-aroscopic access[53].

Number of Veress needle insertions attempts

Studies have reported placing the Veress needle into the peritoneal cavity on the first attempt at frequencies of 85.5% to 86.9%[69,74], two attempts were required in 8.5% to 11.6% of procedures, three attempts in 2.6% to 3.0%, and more than three attempts in 0.3% to 1.6%[49,54]. Complication rates were as follows: at one attempt, 0.8% to 16.3%; at two attempts, 16.31% to 37.5%; at three attempts, 44.4% to 64%; and at more than three attempts, 84.6% to 100%. Complications were extraperitoneal insufflation, omental and bowel injuries, and failed laparoscopy[49,54].

Extraperitoneal insufflation

Extraperitoneal insufflation is one of the most common complications of laparoscopy, frequently leading to abandonment of the procedure because further attempts to achieve pneumo-peritoneum are usually unsuccessful[7,55]. In one study, preperitoneal insufflation occurred in 2.7%, 15%, 44.4%, and 100% of cases at one, two, three, and more than three attempts, respectively[49].

Kabukoba and Skillern described a technique to deal with extraperitoneal insufflation that requires the laparoscope to be left in the preperitoneal space and the gas not evacuated. The Veress needle is then reintroduced into the preperitoneal space in front of the telescope and visually guided into the peritoneal cavity[57].

Veress Needle Modifications

Pressure-sensor-equipped Veress needle

A modified pressure-sensor-equipped Veress needle to provide the surgeon immediate feedback the moment the tip enters the peritoneal cavity has been described[58].

Optical Veress needle (minilaparoscopy)

The Veress needle has been modified to a

2.1 mm diameter and cannula 10.5 cm long to allow insertion of a thin (<1.2 mm diameter), zero degree, semirigid fiberoptic minilaparoscope. This system may be inserted in the umbilicus or the left upper quadrant, and subsequent ancillary ports are inserted under direct vision[9].

During insertion of the assembled unit (Veress cannula and telescope) the surgeon observes a cascade of monitor colour sequences that represent different abdominal wall layers: subcutaneous fat appears yellow, fascia white, anterior rectus muscle red, and peritoneum translucent or shiny bright[59,60]. When the Veress needle enters the peritoneum, CO2 gas can be seen bubbling forwards, and the intra-abdominal structures soon come into view. Alternatively, some surgeons insert the optical Veress needle first, secure insufflation, and then introduce the minilaparoscope[39].

In patients with longitudinal abdominal wall incisions, utilization of the optical Veress system through the LUQ and insertion of the ancillary ports under direct vision may present a safer alternative. However, in a prospective study of 184 cases, two bowel perforations occurred[61]. Therefore, the relative predictive risks of the optical Veress needle remain uncertain in the absence of randomized studies[39,62].

Veress intraperitoneal pressure (VIP pressure)

Several investigators have reported initial intraperitoneal insufflation pressures < 10 mm Hg indicating correct Veress needle placement[49,54,63-67]. Prospective studies have concluded that initial intra-abdominal pressures of 10 mm Hg or below indicate correct placement of the Veress needle, regardless of the women's body habitus, parity, and age[66,67]. In fact, another study concluded that the initial gas pressure (<9 mm Hg) is the only accurate measure of correct intraperitoneal Veress needle placement[49]. Finally, a recent study has confirmed that the initial intraperitoneal insufflation pressure (<10 mm Hg) correlates positively with the patient's weight and BMI and negatively with parity[67].

Adequate Pneumoperitoneum

Controversy exists as to what defines an "adequate," "appropriate," or "sufficient" pneumoperitoneum prior to insertion of the primary trocar. Traditionally, it has been defined by an arbitrary volume of 1 L to 4 L of CO_2 or an arbitrary intraperitoneal pressure of 10 to 15 mm Hg[54]. Richardson and Sutton undertook a prospective study of 836 patients undergoing laparoscopy to determine the complications associated with the first entry, using the volume technique (n=291) and the pressure technique (n=335, median pressure 14 mm Hg) as the end points[54]. The average volume of CO2 used in the pressure technique group was significantly greater than that used with the volume technique group (4.3 vs. 2.8 L; P > 0.01), and the complication rate in the pressure technique group was significantly lower than that in the volume technique group (4.1% vs. 8.2%; %2=5.22, df=1,0.5 >P>0.02), at all levels of operator experience. The authors suggested that the pressure technique should be universally adopted[54].

High Pressure Entry (The HIP Entry)

The pressure technique has been adopted by many surgeons worldwide, but the appropriate volume to establish an appropriate intra-abdominal pressure remains controversial. Final pressures up to 10 mm Hg68, 15 mm Hg[64,69,70], 14 to 18 mm Hg71, 20 mm Hg[38,49] and even 25[63,66,72] to 30 mm Hg[72,73] have been advocated.

The rationale for the higher pressure entry technique is that it produces greater splinting of the anterior abdominal wall and a deeper intra-abdominal CO_2 bubble than the traditional volume-limited pneumoperitoneum of 2 L to 4 L. One study determined that 3 L and 4 L of insufflated CO_2 volume established intraperitoneal pressures of 10 and 15mm

Hg, respectively[72]. The same study demonstrated that when a downward force of 3 kg was applied to an umbilical trocar, the intra-abdominal CO_2 bubble was reduced to zero at 15 mm Hg, and the tip of the trocar touched abdominal contents; when the same force was applied at 25 mm Hg pressure, a CO_2 gas bubble at least 4 cm deep was maintained in all cases, and the tip of the trocar never touched abdominal contents[72]. It has been determined that trocar insertion requires 4 to 6 kg of force, and shielded disposable trocars require half the force of reusable trocars[74,75].

The combined results of three series involving 8997 laparoscopies using entry pressures of 25 to 30 mm Hg included reports of four (0.04%) bowel injuries[17,72,76] and one (0.01%) major vessel injury[17]. In all cases of bowel injuries, the bowel was adhered at the entry site of the anterior abdominal wall, and the vascular injury occurred because of inadvertent loss of pneumoperitoneum during trocar insertion.

Although the high-pressure entry technique is easier for the surgeon and safer for the patient, surgeons may be reluctant to accept it for fear of compromising the patient's cardio-pulmonary function. It has been demonstrated that the use of transient high-pressure pneumoperitoneum causes minor hemodynamic alterations of no clinical significance[72,76]. However, although there is a significant decrease in pulmonary compliance (approximately 20%) from 15 to 30 mm Hg, the maximum respiratory effects at 25 to 30 mm Hg have not been shown to differ from the effect of Trendelenburg position with intra-abdominal pressure at 15 mm Hg[72,76].

Open laparoscopic entry or hasson technique

Hasson first described the open entry technique in 1971[6].The suggested benefits are prevention of gas embolism, of preperitoneal insufflation, and possibly of visceral and major vascular injury.

The technique involves using a cannula fitted with a cone-shaped sleeve, a blunt obturator, and possibly a second sleeve to which stay sutures can be attached. The entry is essentially a mini-laparotomy. A small incision is made transversely or longitudinally at the umbilicus. This incision is long enough to be able to dissect down to the fascia, incise it, and enter the peritoneal cavity under direct vision[6]. The cannula is inserted into the peritoneal cavity with the blunt obturator in place. Sutures are placed on either side of the cannula in the fascia and attached to the cannula or purse-stringed around the cannula to seal the abdominal wall incision to the cone-shaped sleeve. The laparoscope is then introduced and insufflation is commenced. At the end of the procedure the fascial defect is closed and the skin is re-approximated. The open technique is favoured by general surgeons and considered by some to be indicated in patients with previous abdominal surgery, especially those with longitudinal abdominal wall incisions.

Several studies on the benefits and complications of the various laparoscopic entry techniques have been published. Hasson reviewed 17 publications of open laparoscopy by general surgeons (9 publications, 7205 laparoscopies) and gynaecologists (8 publications, 13486 laparoscopies) and compared them with closed laparoscopy performed by general surgeons (7 publications, 90152 patients) and gynaecologists (12 publications, 579510 patients)[77]. Hasson reported that for open laparoscopy the rate of umbilical infection was 0.4%, bowel injury 0.1%, and vascular injury 0%. The corresponding rates for closed laparoscopy were 1%, 0.2%, and 0.2%. Hasson advocated the open technique as the preferred method of access for laparoscopic Surgery[77].

Further analysis of Hasson's review suggests that the prospective studies and surveys indicate that general surgeons experience higher complication rates than gynaecologists with the closed technique, but experience similar complication rates with the open technique. Using the closed technique, the visceral and vascular complication rates were 0.22% and 0.04% for general surgeons and 0.10% and 0.03% for gynaecologists. In a published record of his own 29-year experience with laparoscopy in 5284 patients, Hasson reports only one bowel injury within the first 50 cases[78].

Bonjer et al. published their experience in general surgery and reviewed publications up to 1996 on closed (6 series, n=489335 patients) and open (6 series, n=12444 patients) laparoscopy. The rates of visceral and vascular injury were respectively 0.08% and 0.07% after closed lapa-roscopy, and 0.05% and 0% after open laparoscopy (P=0.002). Mortality rates after closed and open laparoscopy were respectively 0.003% and 0% (NS)[79].

Garry reviewed six reports (n=357257) of closed laparoscopy and six reports and one survey (n=20410) of open laparoscopy performed by gynaecologists. With the closed entry technique, the rates of bowel and major vessel injury were 0.04% and 0.02%, respectively; with the open entry, they were 0.5% and 0%, respectively. When the survey report (n=8000) was excluded, the rate of bowel injury with the open technique was 0.06%. Garry concluded that open laparoscopy is an acceptable alternative method that has been shown to avoid the risk of injury almost completely in normally situated intra-abdominal structures[17].

In its clinical practice guideline on the pneumoperitoneum for laparoscopic surgery, the European Association for Endoscopic

Surgery states

Insertion of the first trocar with the open technique is faster as compared to the Veress needle (grade A). The randomised controlled trials comparing closed (Veress plus trocar) versus open approach have inadequate sample size to find a difference in serious complications. In large outcomes studies there were less complications in the closed group (grade B). Although RCTs found the open approach faster and associated with a lower incidence of minor complications (grade A), the panel cannot favour the use of either access technique. However, the use of either techniques may have advantages in specific patient subgroups (grade B)[70].

A multicentre questionnaire survey of general surgeons (57% responding) reported a relatively high incidence of major injuries; the highest with optical trocars (0.27%), the second highest with the closed technique (0.18%, used 82% of the time), and the lowest with the open technique (0.09%)[80].

In clinical trials that compared closed and open entry techniques, the complication rates were 0.07% and 0.17% for the closed and open techniques, respec-tively[81]. The authors concluded that, in contrast to the findings of Catarci and colleagues[80], the number of entry-related complications with the open entry technique was significantly higher than with the closed entry technique. Hasson et al. conclude “There is no evidence to support abandoning the closed entry technique in laparoscopy; however, the selection of patients for an open or alternative procedure is still recommended[81].

The rate of carbon dioxide embolism was 0.001% in a review of 489 335 closed laparoscopies[79]. Several case reports have detailed fatal or near-fatal coronary, cerebral, or other gas embolism[77]. Such a complication has not been reported at open laparoscopy.

At this time, there is not convincing evidence that the open entry technique is superior to or inferior to the other entry techniques currently available. The open entry technique does have a lower incidence of vascular injuries, but this is balanced by a potentially higher incidence of bowel injury, although this can be mitigated if alternative entry sites are chosen in high-risk patients. Instead of dissecting down at the umbilicus on suspected bowel adhesions, an alternative site of entry may be more appropriate, such as the left upper quadrant or the ninth/tenth intercostal spaces. This could possibly decrease the rate of bowel injury, as these sites are rarely affected by adhesions and have been shown to be safe in small studies when hepatosplenomegaly and stomach distension have been excluded.

Direct trocar entry

Dingfelder was the first to publish (in 1978) on direct entry into the abdomen with a trocar[7]. The suggested advantages of this method of entry are the avoidance of complications related to the use of the Veress needle: failed pneumoperitoneum, preperitoneal insufflation, intestinal insufflation, or the more serious CO2 embolism[80]. Laparo-scopic entry is initiated with only one blind step (trocar) instead of three (Veress needle, insufflation, trocar). The direct entry method is faster than any other method of entry[82,83], however, it is the least performed laparoscopic technique in clinical practice today[21].

The technique begins with an infra-umbilical skin incision wide enough to accommodate the diameter of a sharp trocar/cannual system. The anterior abdominal wall must be adequately elevated by hand, and the trocar is inserted directly into the cavity, aiming towards the pelvic hollow. Alternatively, the abdominal wall is elevated by pulling on two towel clips placed 3 cm on either side of the umbilicus, and the trocar is inserted at a 90° angle[83]. On removal of the sharp trocar, the laparoscope is inserted to confirm the presence of omentum or bowel in the visual field.

There are several retrospective studies published on the safety of this method of entry[40,53,84-86], Although a few studies were prospective, only three (n = 664 patients) were randomized[82,83,87].

The methodology of the three RCTs is sound, and two reported on insertion time as well as morbidity and mortality[80,82]. Nezhat et al. excluded past abdominal surgery but took into account BMI; they showed fewer minor complications with direct trocar entry than with the Veress needle. No major complications occurred in either group (n = 200 patients)[87]. Fewer complications were found with direct trocar insertion, but there was no difference with respect to frequency of multiple attempts or ease of insertion[87].

Byron et al. used the direct entry technique on an unselected group of 937 women. The authors reported more than three attempts to enter the abdomen in 2.7% of cases, failed technique in 1.4%, and a total complication rate of 4.2% (39/937) with a significant increased risk of minor complications ($P<0.001$). A history of abdominal surgery was not associated with an increased risk of complications[8]. Subsequently, Byron et al. randomized 252 women into Veress needle (n=141) and direct trocar insertion (n=111) for laparoscopy[82]. The authors reported a four-fold increase of minor complications with the Veress needle over the direct entry method (11.3% vs. 2.7%, $P<0.05$) and a significantly longer insertion time (5.9 vs. 2.2 min, $P<0.01$). Similarly, Borgatta et al. included women with previous surgery and demonstrated a two-fold increase in omental injury with the Veress needle over the direct trocar insertion and a longer insertion time of 2 minutes and 10 seconds with the Veress needle[83].

Copeland et al. reported on 2000 unselected women with whom direct trocar insertion was utilized. Eight cases (0.4%) required conversion to insufflation with Veress needle, and one of these resulted in bowel injury. Two additional bowel injuries were encountered with the direct trocar entry (0.1%)[85].

Hill and Maher perforated the omentum with the direct trocar in 26 of 542 patients (4.8%), as it was elevated with peritoneum[53]. Molloy et al. reported on a review of 51 publications including 134 917 Veress/trocar, 21 547 open, and 16 739 direct entries[21]. Entry-related bowel injury rates were 0.04% (Veress/trocar), 0.11% (open), and 0.05% (direct entry); corresponding vascular injury rates were 0.04%, 0.01%, and 0%, respectively[21]. Case reports of major vessel injury with direct entry have been reported[88]. Five deaths were reported among the studies of case reports, all occurring in the Veress/trocar group. Two deaths were attributable to delayed diagnosis of bowel perforation and three were attributable to gas embolism during insufflation[89]. The calculated overall mortality associated with laparoscopic entry was 1 per 100 000 procedures[21]. Bowel injury is reported more frequently in general surgical patients than in gynaecological patients 0.15% versus 0.04% (P=0.0001). Vascular injuries during open and direct entry technique have an identical incidence of 0.0%[21]. The authors concluded that “there is no clear evidence as to the optimal form of laparoscopic entry in the low-risk patient. However, direct entry may be an under-utilized and safe alternative to the Veress needle and open entry technique[21].

Sharp trocars are recommended for a direct insertion technique. Reusable trocars are not subject to a standardized frequency of sharpening[15,87]; Yuzpe reported that a higher proportion of women than men experienced difficulty inserting both the primary and secondary trocars[87]. In addition, injuries appeared to occur twice as often amongst those gynaecologists who experienced difficulty with trocar insertion (P = 0.04). When difficulty was associated with the primary trocar, the correlation was even more striking (P=0.02)[87].

Disposable shielded trocars

Disposable shielded “safety” trocars were introduced in 1984[4]. These trocars are designed with a shield that partially retracts and exposes the sharp tip as it encounters resistance through the abdominal wall. As the shield enters the abdominal cavity, it springs forward and covers the sharp tip of the trocar.

These trocars were intended to prevent the sharp tip from injuring intra-abdominal contents. However, it must be pointed out that even when a shielded trocar functions properly and is used according to the specifications, there is a brief moment when the sharp trocar tip is exposed and unprotected as it enters the abdominal cavity[90,91].

In the presence of pneumoperitoneum, disposable shielded trocars have been shown to require half the force needed for a reusable trocar. The force required to enter the abdomen with various disposable trocars in the pig model was 4 to 6 kg[74,92]. Increased entry force frequently results in loss of operator control and overthrusting of the trocar, which is a potential cause of serious vascular and visceral injuries[92].

In a randomized study of 100 direct laparoscopic entries, no complications occurred with the disposable trocars (n= 50), and three (6%) minor complications occurred with the conventional trocars (P> 0.05). Ten cases in each group required two insertions, and failed insertion occurred in 8% and 4% of cases (P>0.05) in the conventional and disposable trocar groups, respectively[87].

Champault et al. reported on 103 852 operations involving the use of 386 784 trocars. They found that 10 out of 36 (28%) serious injuries and two out of seven (29%) deaths involved shielded trocars[93]. Saville and Woods reported four major retroperitoneal vessel injuries in 3 591 laparoscopies, all of which involved shielded trocars[94]. Marret et al. reported 47 complications due to trocar insertions between 1994 and 1997. Half of the trocars used were disposable and this type of so-called safety trocar was responsible for half of the large blood vessel injuries[47].

Bhoyrul et al. analyzed 629 trocar injuries reported to the FDA database from 1993 to 1996. There were 408 injuries to major vessels, 182 injuries to other viscera (mainly bowel), and 30 abdominal wall hematomas. Of the 32 deaths, 26 (81%) resulted from visceral injuries, and 6 (19%) resulted from vascular injuries. Eighty-seven percent of deaths from vascular injuries involved the use of disposable trocars with safety shields, and 9% involved disposable optical trocars. Ninety-one percent of bowel injuries involved trocars with safety shields, and 7% involved optical trocars. The diagnosis of bowel injury was delayed in 10% of cases, and the mortality rate in this group was 21%. The authors concluded that safety shields and direct-view trocars cannot prevent serious injuries during laparoscopic access[71]. Furthermore, the data would not support a contention that safety-shield malfunction was a common factor. There were few reports in which a safety-shield malfunction was alleged to have contributed and even fewer in which malfunction was actually found[71].

Finally, the FDA in a letter to the manufacturers of laparo-scopic trocars, dated August 23, 1996, requested that, in the absence of clinical data showing reduced incidence of injuries, manufacturers and distributors voluntarily eliminate safety claims from the labelling of shielded trocars and needles[95].

In 1998 and 2000, the Emergency Care Research Institute (ECRI) concluded that although shielded trocars do not totally protect against injuries, they are preferable to unshielded trocars[90,91]. A trocar use survey of 62 health care facilities reported that shielded trocars were used for primary trocar entry by 37% of surgeons for 100% of procedure, by 59% for at least 90% of procedures, and by 79% for at least 80% of procedure[96].

Radially expanding access system

The radially expanding access system (Step, InnerDyne, Sunnyvale, CA) was introduced in 1994. It consists of a 1.9 mm Veress surrounded by an expanding polymeric sleeve. The abdomen may first be insufflated using the Veress needle. The needle is removed, and the sleeve acts as a tract through the abdominal wall that can be dilated up to 12 mm by inserting a blunt obturator with a twisting motion[97,98]. The force required to push this trocar through the abdomen in pigs is 14.2 kg compared with forces of 4 to 6 kg needed for disposable trocars[92].

Several case series and randomized studies have reported no injury to major vessels and no deaths[21]. Abdominal wall bleeding and Veress injury to mesentery have been encountered[21]. In addition, RCTs have demonstrated less post-operative pain and more patient satisfaction with the radially expanding device than with the conventional trocar entry techniques[98-102].

Advantages of this system include elimination of sharp trocars, application of radial force, stabilization of the can-nula's position (cannula does not slide in and out), avoidance of injury to abdominal wall vessels, and elimination of the need for suturing of fascial defects.

Visual entry systems

Disposable optical trocars

Optical/access trocars were introduced in 1994[4] and are popular among urologists. Two disposable visual entry systems are available that retain the conventional trocar and cannula push-through design: the Endopath Optiview optical trocar (Ethicon Endo-Surgery, Inc., Cincinnati, OH) and The Visiport optical trocar, (Tyco-United States Surgical, Norwalk, CT). These single-use visual trocars trade blind sharp trocars for a hollow trocar, in which a zero degree laparoscope is loaded for the distal crystal tip to transmit real-time monitor images while transecting abdominal wall tissue layers. Their application recruits significant axial thrust through the surgeon's dominant upper body muscles to transect abdominal myofascial layers.

Endopath Optiview optical trocar

The Endopath Optiview optical trocar comprises a hollowed trocar and a cannula. When insufflation is complete, the Veress needle is withdrawn, and the subcutaneous fatty tissue is dissected off, using peanut sponges, to expose the white anterior rectus fascia. A 5 mm incision is then made with a scalpel to accommodate the visual trocar's pointed tip.

When the Endopath optical trocar is used directly, without pre-insufflation, two anterior rectus fascia stay sutures are placed at 3 and 9 o'clock and held with snaps. The fascia is then divided between the stay sutures over a length of approximately 5 mm. During insertion, the stay sutures are pulled to lift the abdominal wall against the advancing trajectory and facilitate proper port site closure at the end of the operation. Alternatively, the assistant may grasp the abdominal wall with towel clips, while the surgeon negotiates the visual trocar[103].

Twisting the handle advances the hydrophobic and winged trocar tip to dissect successive tissue layers on its way towards the abdomen. The cascade of generated entry images displayed on the monitor demonstrates level of penetration.

Some surgeons advocate use of visual trocars during gasless laparoscopy, in which abdominal wall lifting devices are used to tent the abdominal wall before the primary visual trocar is inserted under visual control. Experience with such methods is limited, and large-scale studies are lacking[104].

Visiport optical trocars

The Visiport optical trocar is a disposable visual entry instrument that comprises a hollow trocar and a cannula. Every trigger squeeze advances the sharp cutting knife 1 mm to transect tissue in contact with the crystal tip and swiftly retract back into the crystal hemisphere. It is advised that, as with other visual trocars, the Visiport optical trocar is to be applied only after CO2 insufflation[105].

When insufflation is complete, the Veress needle is withdrawn, and subcutaneous fatty tissue is dissected off the white anterior rectus fascia using peanut sponges. The Visiport optical trocar is palmed by the surgeon's dominant hand and held perpendicular to the supine patient's CO_2 distended abdomen. Once the exact anatomical position of the trocar tip is verified on the monitor, downward axial pressure is applied while activating the trigger. Then downward pressure is relieved, the trigger released, and the trocar tip position verified on the monitor again. This entry sequence is repeated until the peritoneal cavity is entered. The trigger is not fired until the exact anatomical position of the trocar tip is known.

The push-through entry design requires significant perpendicular force to drive a trajectory across tissue planes with no means of avoiding trocar overshoot. Sometimes, the anterior abdominal wall may be grasped with the non-dominant hand of the surgeon and lifted to offer counter pressure against the advancing trocar. The Visiport optical trocar comes in only one diameter and accommodates only a 10 mm laparoscope.

EndoTIP visual cannula

The endoscopic threaded imaging port, EndoTIP (Karl STORZ Endoscopy, Tuttlingen, Germany), is a reusable visual cannula system that allows real-time interactive port creation, when port-dynamics are archived, for recall and analysis. The principal differentiating aspects of EndoTIP include reduction of push-force, visually controlled entry, elimination of overshoot, and lack of sharp trocar.

Conventional primary trocar insertion requires application of considerable axial push-force (2–14 kg)[74,75] to the trocar and cannula where the anterior abdominal wall dents towards the viscera; entry is blind. The EndoTIP consists of a stainless steel cannula with a proximal valve segment and distal hollow threaded cannula section. The conventional valve sector houses a standard CO_2 stopcock, and the can-nula's outer surface is wrapped with a single thread, winding diagonally to end in a distal blunt notched tip. The cannula is available in different lengths and diameters for different surgical applications. A retaining ring keeps the mounted laparoscope from sliding out of focus during insertion[106].

The EndoTIP visual cannula system requires no trocar and has no crystal tip compressing and distorting monitor images at tissue–cannula interface. Interpretations of observed monitor images are identified, layered-entry, and real-time interactive.

A generous umbilical skin incision is made using a surgical blade to avoid skin dystonia. Ribbon retractors and peanut sponges are used to expose the white anterior rectus fascia. As when using the optical trocar, insertion starts at the fascial level. A 7 mm rectus fascial incision is then made under direct vision, and the Veress needle is inserted through the fascial incision with the CO_2 stopcock in the open position. When insufflation is complete, the surgeon holds the laparoscope with mounted cannula perpendicular to patient's supine abdomen, using the non-dominant hand. The unit, (laparoscope and mounted cannula) with the CO_2 stopcock in the closed position is then lowered into the umbilical wound. The surgeon uses the muscles of the dominant wrist to rotate the cannula clockwise, while keeping the forearm horizontal to the patient's abdomen. Downward axial pressure during rotation is kept to a minimum.

The blunt cannula's notched tip engages the anterior rectus fascial window and stretches it radially. Rotation applies Archimedes' principle to lift the anterior abdominal wall and transpose successive tissue layers onto the cannula's outer thread. The white anterior rectus fascia, red rectus muscle, pearly white posterior rectus fascia, yellowish preperitoneal space, and transparent greyish peritoneal membrane are all observed sequentially on the monitor.

As the cannula has no cutting or sharp end, tissue layers are not transected; instead, they are taken up along the outer pitch. The parted tissue layers preserve port competence and result in a smaller fascial entry wound area with less muscle damage than with pyramidal trocar wounds[107].

Further clockwise rotation parts the peritoneal membrane radially to advance the cannula incrementally into the peritoneal cavity under direct visual control, while avoiding cannula overshoot.

Recommendations and Summary Statement

1. Left upper quadrant (LUQ, Palmer's) laparoscopic entry should be considered in patients with suspected or known periumbilical adhesions or history or presence of umbilical hernia, or after three failed insufflation attempts at the umbilicus. Other sites of insertion, such as transuterine Veress CO_2 insufflation, may be considered if the umbilical and LUQ insertions have failed or have been considered and are not an option.

2. The various Veress needle safety tests or checks provide very little useful information on the placement of the Veress needle. It is therefore not necessary to perform various safety checks on inserting the Veress needle; however, waggling of the Veress needle from side to side must be avoided, as this can enlarge a 1.6 mm puncture injury to an injury of up to 1 cm in viscera or blood vessels.

3. The Veress intraperitoneal (VIP-pressure 10 mm Hg) is a reliable indicator of correct intraperitoneal placement of the Veress needle; therefore, it is appropriate to attach the CO_2 source to the Veress needle on entry.

4. Elevation of the anterior abdominal wall at the time of Veress or primary trocar insertion is not routinely recommended, as it does not avoid visceral or vessel injury.

5. The angle of the Veress needle insertion should vary according to the BMI of the patient, from 45°. in non-obese women to 90° in obese women.
6. The volume of CO_2 inserted with the Veress needle should depend on the intra-abdominal pressure. Adequate pneumo-peritoneum should be determined by a pressure of 20 to 30 mm Hg and not by predetermined CO_2 volume.
7. In the Veress needle method of entry, the abdominal pressure may be increased immediately prior to insertion of the first trocar. The high intraperitoneal (HIP-pressure) laparoscopic entry technique does not adversely affect cardiopulmonary function in healthy women.
8. The open entry technique may be utilized as an alternative to the Veress needle technique, although the majority of gynaecologists prefer the Veress entry. There is no evidence that the open entry technique is superior to or inferior to the other entry techniques currently available.
9. Direct insertion of the trocar without prior pneumoperitoneum may be considered as a safe alternative to Veress needle technique.
10. Direct insertion of the trocar is associated with less insufflation-related complications such as gas embolism, and it is a faster technique than the Veress needle technique.
11. Shielded trocars may be used in an effort to decrease entry injuries. There is no evidence that they result in fewer visceral and vascular injuries during laparoscopic access.
12. Radially expanding trocars are not recommended as being superior to the traditional trocars. They do have blunt tips that may provide some protection from injuries, but the force required for entry is significantly greater than with disposable trocars.
13. The visual entry cannula system may represent an advantage over traditional trocars, as it allows a clear optical entry, but this advantage has not been fully explored. The visual entry cannula trocars have the advantage of minimizing the size of the entry wound and reducing the force necessary for insertion. Visual entry trocars are non-superior to other trocars since they do not avoid visceral and vascular injury.

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