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Review

Vascular injury during laparoscopic gynaecological surgery: a methodological approach for prevention and management

Gemma Brierley MBBS BA (Hons) DFSRH MRCOG,[a]* **Ilyas Arshad** MBChB MRCS MMedSci MRCOG,[b] **Fevzi Shakir** MBBS BSc(Hons) MRCOG MSc,[c] **Dilip Visvathanan** MBBS MD FRCOG,[d] **Kirana Arambage** MBBS DFFP MSc MRCOG[b]

[a]Consultant Obstetrician and Gynaecologist, West Suffolk Hospital, Hardwick Lane, Bury St Edmunds, Suffolk IP33 2QZ, UK
[b]Consultant Gynaecologist, Oxford University Hospitals, John Radcliffe Hospital, Headley Way, Headington, Oxford OX3 9DU, UK
[c]Consultant Gynaecologist, Royal Free Hospital, Pond Street, Hampstead, London NW3 2QG, UK
[d]Consultant Gynaecologist, Barts Health NHS Trust, Whipps Cross Hospital, Whipps Cross Road, London E11 1NR, UK
**Correspondence:* Gemma Brierley. Email: gemma.brierley@wsh.nhs.uk

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Key content

- Major vascular injuries occur in up to one in 200 laparoscopies, most commonly during Veress needle insertion or primary trocar entry; laparoscopic surgeons should rehearse actions to be taken in case of injury.
- Vascular injury during laparoscopy is associated with significant morbidity and up to 23% mortality.
- Risk factors include previous surgery, intra-abdominal pathology, low/high body mass index and complex surgeries.
- Techniques to manage vascular injury include aggressive fluid resuscitation, hyperbaric pressure, blood transfusion, manual pressure, considering conversion to an open midline laparotomy and the involvement of a vascular or general surgeon.
- Standardised assessment and management protocols should be rehearsed and available in all units.

Learning objectives

- To be aware of the incidence of laparoscopic vascular injury and the potential complications that can occur.
- To recognise key risk factors for vascular injury and ways to prevent injury occurring.
- To rehearse drills on systematic emergency management of laparoscopic bleeding to standardise care; this is ideally suited to the realms of multidisciplinary simulation scenario-based training, to improve a team's response to a vascular injury.

Ethical issues

- Are women who are at increased risk of vascular injuries appropriately counselled regarding complications and consequences, and are they given the options for alternative management?

Keywords: complications / laparoscopy / prevention / risk management / vascular injury

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Introduction

Vascular injury complicates approximately 0.1–1.1% of all laparoscopic procedures.[1-3] While uncommon, major vascular injury is associated with a mortality risk ranging from 8% to 23%,[4,5] making it the second most common cause of death from laparoscopy after anaesthetic complications. The type of surgery,[1,3] the patient's body mass index (BMI) and previous surgical history are risk factors for vascular injury. While a laparoscopic approach gives superior vision for the prevention and treatment of minor vascular injuries, management of major vascular injury is more challenging in laparoscopic surgery than in open surgery.[6] Conversion to laparotomy for management of major vascular injury therefore occurs in one in 380 laparoscopies.[7] This figure is lower in units that are used to managing all laparoscopic complications without converting to laparotomy.

This article aims to describe the injuries that can occur during laparoscopic gynaecological surgery and the evidence relating to how to avoid such injuries, as well as to highlight methods for managing injuries if they occur to minimise the patient's risk of morbidity and mortality.

Key considerations for reducing vascular injury in laparoscopic gynaecological surgery

Preoperative assessment

Surgery should only be undertaken on patients in whom the benefits outweigh the risks. Women should be thoroughly counselled about the risks, including that of vascular injury, before undergoing laparoscopic surgery. In the elective setting, appropriate preoperative assessment, including identification and treatment of anaemia, should be

performed to ensure that intraoperative bleeding is tolerated as well as possible. In the emergency setting, availability of transfusable blood should be ensured in case of injury and consideration given as to whether cell salvage could be used.

Laparoscopic abdominal entry techniques

Seventy-five percent of vascular injuries occur at the time of entry using either a Veress needle or primary trocar.[8] Traumatic injuries are less common with secondary trocars because they are inserted under direct vision.[9] Evidence about the safest laparoscopic entry technique is mixed,[10] with some preference for the open Hasson entry technique to reduce major vascular injury. The Royal College of Obstetricians and Gynaecologists' Green-top Guideline[11] recommends open entry or use of Palmer's point in women with a low BMI to reduce the risk of posterior abdominal wall vascular injury.

A review of all vascular injuries reported to the US Food and Drug Administration between 1993 and 1996 concluded that safety shields, which cover the trocar tip before and after insertion, and direct view trocars cannot prevent serious injuries. Eighty-seven percent of deaths resulting from vascular injury were associated with the use of a trocar with a safety shield.[7]

Abdominal pressure

Initial Veress pressure of less than 8 mmHg has been reported by numerous investigators to indicate correct entry to the peritoneum.[11,12] Complication rates increase with the number of attempts of insertion of a Veress needle – up to 64% after three attempts.[11] The Royal College of Obstetricians and Gynaecologists recommends an alternative method of entry, either open Hasson or Palmer's point, after two unsuccessful attempts to insert the Veress needle via the umbilicus.[13]

Increasing the pneumoperitoneum pressure to at least 20 mmHg is associated with an increased distance between the insertion point and the retroperitoneal vessels. With a downward force of 3 kg at the umbilicus, the mean vertical depth of pneumoperitoneum was 0.6 cm with pressure of 10 mmHg. If the pressure was increased to 25 mmHg, the distance was 5.6 cm (range 4–8 cm). Richardson et al. [14] highlight that the use of increased abdominal pressures may require the anaesthetist to use increased ventilator pressures to maintain adequate ventilation. High abdominal pressures should only be used during initial entry before reducing the pressure to 10–15 mmHg. Visual cannulae do not seem to reduce the incidence of injury.[14]

Previous surgery

Previous surgery is a risk factor for complications in further laparoscopy. Peri-umbilical adhesions are found in 0.68% of women with no previous surgery, in 1.6% of those with previous laparoscopic surgery, in 19.8% with previous transverse laparotomy and in 52% with previous midline laparotomy.[15]

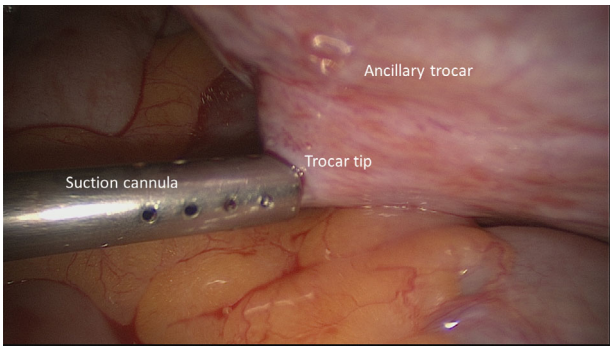

Figure 1. Tip-directed entry.

A site other than the umbilicus should be considered in those who have had previous surgery. Palmer's point, 3 cm below the left subcostal margin in the mid-clavicular line, is a well-recognised alternative site for Veress needle entry. Once the pneumoperitoneum has been created, a 5-mm trocar can be inserted at Palmer's point to assess for adhesions around the umbilicus before inserting the operating trocar at the umbilicus if necessary and safe to do so.

Tinelli et al.[16] have published a tip-entry guided technique that aims to avoid vascular injury during the insertion of second and further ancillary trocars. Following the introduction of the first ancillary trocar, a suction cannula is placed via the first ancillary trocar and directed to the point of introduction for the second trocar. The surgeon can then guide the tip of the trocar into the suction cannula, ensuring that the sharp tip is protected during entry with the tip of the trocar completely inside the suction cannula (Figure 1).

Box 1 summarises the elements of best practice in laparoscopic abdominal entry techniques.

Box 1. Elements of best practice in abdominal entry techniques

- Use the entry technique with which you are most familiar unless there are specific reasons to use an alternative method
- Avoid previous scars when choosing the entry point
- Make an adequate skin incision to avoid the need for the use of excessive pressure to pass the trocar through the skin
- If using the Veress needle, insert it vertically and stop insertion as soon as the peritoneum is penetrated[15]
- Consider insertion of Veress and primary trocar with the woman in a supine rather than Trendelenburg position
- Increase the pneumoperitoneum pressure to at least 20 mmHg before inserting trocars
- Consider open technique or Palmer's point entry in women with a low body mass index or previous surgery

Instruments

Unintended electrosurgical arcs can occur from monopolar instruments. There are reports of vascular injury, including injury to the external iliac artery, resulting from failure of the insulating sheath of monopolar scissors.[17] Inadvertent thermal injury can occur if energy devices (including advanced devices) are activated excessively.[18] Good knowledge of the instruments being used and the anatomical spaces, as well as vigilance in recognising injuries when they occur, is essential to reduce surgical morbidity.

Camera angle

Surgeons and their assistants should be encouraged to keep the camera tilt as close to zero degrees as possible. Injury is more likely in the presence of camera tilt greater than 15 degrees. This is likely due to misidentification of anatomical structures.[19]

Vessels at risk in laparoscopic gynaecological surgery

An understanding of the surgical anatomy of the vessels at risk of injury during laparoscopic surgery is an important step in reducing vessel injury. Anterior abdominal wall vessels and retroperitoneal vessels can be injured during Veress needle, primary trocar or secondary port insertion.

In addition to injuries on entry, vessels can be damaged during dissection, electrosurgery or use of other energy devices. Box 2 summarises the vessels at risk in laparoscopic gynaecological surgery.

Inferior epigastric artery

The inferior epigastric artery arises from the external iliac artery, close to the insertion of the round ligament. It pierces the transversalis fascia and runs along the transverse abdominis muscle and the rectus sheath. At the umbilicus, it lies between 3 cm and 6 cm from the midline; at the pubic symphysis, it lies 1.2–7.5 cm from the midline.[20] There is a 'safe zone' where ports can be inserted with a low likelihood of injuring the inferior epigastric artery. This could be from <1 cm from the midline or >8 cm from the midline. Insertion of ports more than two-thirds along the line between the midline and the anterior superior iliac spine will also fall in this 'safe zone'.

Direct visualisation of the inferior epigastric artery by Doppler ultrasound or transillumination has been recommended, but this becomes more difficult with increasing BMI. Tinelli et al.[16] describe a 'yellow island' which exists one-third of the way from the anterior superior iliac spines to the umbilicus and can be identified easily in those with increased BMI (Figure 2). This yellow zone can be used for safe placement of secondary ports. Inserting ports perpendicular to the abdominal wall also helps to minimise inadvertent inferior epigastric artery injury.

Aorta

Most surgeons use the umbilicus as the site for insertion of the Veress needle and primary trocar. During insertion of these instruments, the aorta, inferior vena cava and common iliac vessels are at risk of injury.

The abdominal aorta bifurcates into the right and left common iliac arteries at the level of L4. In the supine position, the aortic bifurcation ranges from 5 cm cephalad to 3 cm caudal to the umbilicus (Figure 3).[21] In the Trendelenburg position, it ranges from 3 cm cephalad to 3 cm caudal to the umbilicus. Aortic bifurcation occurred

Box 2. Vessels at risk in laparoscopic gynaecological surgery

Anterior abdominal wall
- Inferior epigastric artery
- Superficial circumflex iliac artery

Posterior abdominal wall
- Aorta
- Common iliac arteries and veins
- External iliac artery and vein
- Internal iliac artery and vein
- Inferior vena cava
- Corona mortis

Other
- Omental vessels
- Mesenteric vessels

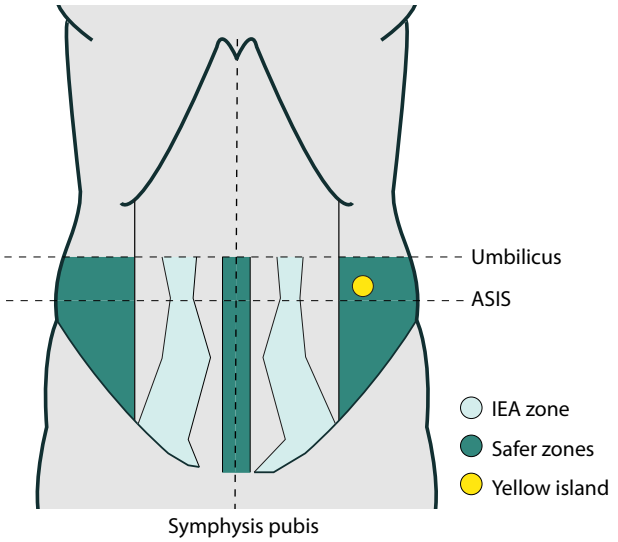

Figure 2. Areas likely to contain the inferior epigastric artery, safer areas and Tinelli's 'yellow island'.[16] ASIS = anterior superior iliac spine; IEA = inferior epigastric artery.

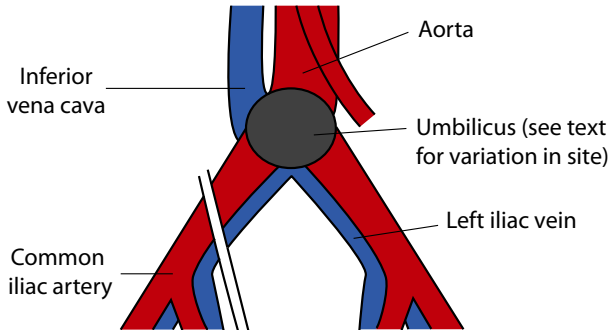

Figure 3. Relationship of the umbilicus to underlying great vessels.

caudal to the umbilicus in 33% of laparoscopies carried out in a Trendelenburg position versus 11% in a supine position.[21] This supports insertion of the Veress needle and first trocar in the supine position before raising the legs into the Trendelenburg position. These findings were not affected by the patient's BMI.

If the aorta is injured, the haemorrhage may be visible during primary survey of the abdomen on entry with the camera. However, in cases of small vessel puncture, the bleeding may result in the formation of a retroperitoneal haematoma that is not immediately apparent. Surgeons should respond promptly to any concern from the anaesthetist regarding haemodynamic instability, such as unexpected hypotension or tachycardia, and consider the presence of any bleeding, including retroperitoneal.

Common iliac arteries

As the aortic bifurcation occurs just to the left of the midline, the right common iliac artery is at higher risk of injury during instrumentation of the umbilicus than the left. Keeping the Veress needle and trocar in the midline during entry minimises the risk of injury to these vessels.

Venous system

The vena cava is formed by the confluence of the common iliac veins. This occurs anterior to the L5 vertebra, caudal to the bifurcation of the aorta and approximately 2.5 cm to the right of the midline. An injury to the vena cava is therefore more likely when a trocar is inserted next to the midline instead of in the midline. The left iliac vein crosses the midline caudal to the umbilicus and can be injured even by a midline trocar.

Sharp dissection may cause injury that requires repair. The walls of the major veins are delicate and injury can lead to catastrophic bleeding. Blunt dissection along the common iliac vein, inferior vena cava, pelvic sidewall or the presacral area can avulse small tributaries from larger veins with resultant haemorrhage.

Corona mortis

The corona mortis is an anastomosis between the obturator and the external iliac or inferior epigastric arteries or veins situated behind the superior pubic ramus, which may be injured during pelvic lymphadenectomy.

Anterior abdominal wall vascular injury

The most common vascular injury overall is laceration of the inferior epigastric artery during placement of lateral trocars (usually as secondary trocars) in the lower abdomen.

Bleeding from the port sites may present immediately, disturbing the intraoperative view at the time of surgery, or it can be delayed. If recognition of the injury is delayed, bleeding is usually noted within an hour of transfer from the operating theatre. Delayed abdominal wall haematomas can present 2–3 days after surgery with abdominal wall pain, or abdominal wall or flank ecchymosis.

If bleeding is noted immediately, the following techniques may be employed:

- Electrosurgery to coagulate the bleeding point is often successful. Surgeons should be aware that occasionally bleeding vessels may appear to have been coagulated but in fact have retracted from the peritoneal surface.[22] If this is not recognised, delayed haematomas may form.
- A Foley catheter may be inserted through the port site, and the balloon inflated in the peritoneal cavity. The balloon can then be pulled up against the bleeding point with a resultant tamponade effect.
- The lacerated inferior epigastric vessels can be sutured using an Endo Close™ suture, a straight needle or intracorporeal suturing. This can be passed under direct laparoscopic vision superior and inferior to the bleeding vessel.
- Management should be conservative if the woman has an abdominal wall haematoma but is hemodynamically stable with no signs of haematoma expansion. Intervention is indicated if the haematoma is expanding and the woman becomes hemodynamically unstable or septic secondary to an infected haematoma.
- Percutaneous embolisation of the bleeding vessel can be undertaken if interventional radiology is readily available.
- Conversion to open surgery may be considered for rapidly expanding haematomas or those in women who are haemodynamically unstable. A low transverse incision can be used, but if there is any doubt about it being sufficient, a midline incision should be made.

Posterior abdominal wall vessel injury

Injuries to the posterior abdominal wall vessels are potentially life-threatening vascular injuries, which demand

Box 3. Recognition of vascular injury during laparoscopy

- Retroperitoneal haematoma (stable or enlarging in size) may be seen superior to the sacral promontory area
- Active bleeding coming directly from the major vessels
- Free blood in the abdominal cavity
- Haemodynamic instability

early recognition, prompt coordinated resuscitation and arrest of bleeding.[23]

Understandably, there are no randomised controlled trials providing reliable recommendations as to whether the management should be laparoscopic or by laparotomy. In each situation, this clinical decision should be taken by the lead surgeon depending on their level of expertise, experience, technical and institutional assistance available.[24]

When the patient is haemodynamically compromised and a major vascular injury is suspected or diagnosed, then immediate conversion to midline laparotomy is advised.[25-27] It is easier and safer to carry out a laparotomy while there is still a pneumoperitoneum. Once the abdomen is entered, the bleeding point is sought to apply direct pressure to stop the bleeding, while simultaneously other members of the team call for help and blood products.[28] If the primary surgeon is experienced, or once vascular expertise has arrived, they may wish to clamp the vessel above and below the bleeding point, so they can repair the vascular injury using one of the various techniques they feel appropriate to employ: sutures, clips, energy devices or haemostatic patches/sealants.[23]

Advanced techniques to manage vascular injury include primary repair, polytetrafluoroethylene graft interposition or Dacron patchplasty.[25-27]

Minor vascular injuries during the operation can be managed using laparoscopic techniques such as direct pressure using Johan atraumatic grasping forceps, mastoid swabs, electrocautery energy, intracorporeal/extracorporeal suturing, clips and haemostatic agents.

Box 3 indicates how vascular injury during laparoscopy may be recognised.

Immediate action proposed for the gynaecologist following a major vascular injury

Major vascular injury at laparoscopy can be life threatening and challenging, and requires a multidisciplinary approach to obtain an optimum outcome for the woman. Successful management of major haemorrhage is facilitated by early recognition, remaining calm, replacing circulating blood volume and ensuring cessation of further blood loss.

The immediate management of major vascular injury will be the same regardless of the type of hospital and the gynaecologist's expertise. Immediate management steps are outlined below.

1. Declare a major vascular emergency

This is a very important key step from human factors training.[29] Early declaration is associated with better team efficiency. All team members must realise this is a potentially life-threatening emergency and be available to help with an organised team approach.

If the situation allows, the leader, usually the surgeon, should aim to stop for a brief moment and step back to organise their thoughts.

2. Arrest the bleeding with direct pressure

Major vascular injury usually requires a midline laparotomy; however, in certain circumstances it may be possible to deal with it laparoscopically, depending on the operator's level of skill and experience.[30] A multidisciplinary team approach is advocated, seeking senior surgical help depending on the level of competency of the operator. This may include vascular or general surgery input.

Leaving the trocar that caused the injury in place rather than removing it will limit blood loss while preparations can be made for resuscitation and repair.

If vascular injury below the bifurcation of the aorta is suspected but not visible clearly and laparotomy is considered, direct pressure on the vessel using laparoscopic instruments should be employed. In addition, external pressure on the aorta just underneath the xiphisternum may decrease further blood loss until the abdomen is opened and direct pressure or vascular clamps are applied.

3. Communicate effectively with the team

Objectives should be verbalised clearly to the team. Critical tasks should be allocated to specific team members with closed loop communication and a structured handover, such as SBAR (situation, background, assessment, recommendation). This approach is associated with higher team efficiency in the performance of critical tasks and administration of essential drugs.[31]

Anaesthetist colleagues may delegate a member of the team to communicate with the switchboard and blood bank to announce the major haemorrhage protocol to obtain high-priority blood products. The surgeon and the anaesthetist should clearly request any additional equipment and personnel required to assist with managing the vascular injury.

4. Resuscitate and continue fluid resuscitation

The anaesthetic team need to site sufficient peripheral access to give fluids/emergency medication. An indwelling catheter, if not already present, should be inserted to assist with fluid balance management.

5. Monitor and investigate

More invasive monitoring may be required in the form of arterial/central lines. While intravenous access is obtained, blood can be taken for urgent full blood count, urea and electrolytes, liver function tests, coagulation screen and cross-match samples.

6. Other considerations

The team leader or circulating nurse can help direct and supervise actions in the operating theatre. Closing theatre doors helps to keep the environment relatively relaxing and quiet, prevents accumulation of professionals and supports the anaesthetist. It is important to keep on top of swab counts and empty clinical bins.

Theatre staff can obtain more appropriate equipment such as laparotomy/vascular sets, more specialised laparoscopic equipment (Johan atraumatic grasping forceps), mastoid swabs, swabs for open operation and counting trays.[32] In addition, it is a good idea to inform and update the woman's partner or family members, as soon as is possible under these circumstances.

7. Risk management

A team member needs to scribe all that is occurring in time sequence. An incident form will need to be completed once the medical emergency has been dealt with. Contemporaneous notes will be useful to the department when reflecting on the case, from a representative of all the teams involved.

Retrospective documentation from all staff members is extremely useful when looking back on the case to learn from it in order to improve the management of vascular injuries in the future.

Postoperative care

In the immediate postoperative period, fluid balance and haemodynamic stability must be closely monitored. This may require care in an intensive care unit/high dependency unit. Continuing antibiotics may be required if there is evidence of infection or as prophylaxis. The risk of venous thromboembolism should be assessed and consideration given for the need for thromboprophylaxis; this may be mechanical initially, given the high risk of continuing bleeding.

Later postoperative care requires a thorough debrief with the woman and her family to explain the complications and any implications. In the case of major vessel injury in women of reproductive age, advice to avoid pregnancy for several months to allow successful vessel healing before the haemodynamic challenge of pregnancy would be prudent.

Case studies

1. A young woman was being investigated for primary infertility with a diagnostic laparoscopy and dye test. She had a normal BMI and no previous medical or surgical history. At the time of Veress entry, she sustained a direct penetrating injury to the inferior vena cava. On insertion of the laparoscope, a stable 8 cm-sized retroperitoneal haematoma was visible near the sacral promontory. The woman was haemodynamically stable. A vascular emergency was declared and a major haemorrhage call was put out. Further intravenous access and senior support was summoned. As the woman was haemodynamically stable and there was no change in size to the haematoma, the senior surgeon decided to await the arrival of a vascular surgeon. The abdominal pressure was kept at 20 mmHg to minimise further bleeding. The vascular surgeon arrived and advised decreasing the abdominal pressure to 4 mmHg with watchful waiting for another 30 minutes. As the patient remained stable, a contrast computed tomography (CT) angiogram was arranged to identify any active extravasation of contrast media. In this case, there was no active extravasation and the woman was managed conservatively. She was recovered in the intensive care unit for the next 12 hours adjacent to emergency theatres until she was deemed stable to return to the ward. Had active extravasation been seen on CT, or had the woman deteriorated clinically, the plan was for a midline laparotomy and suturing of the bleeding point.
2. A 65-year-old woman was undergoing a laparoscopic anterior resection for bowel cancer. During the Veress needle insertion, the aorta was punctured. The woman was stabilised with intravenous fluids and then transferred from the district general hospital to the nearest tertiary centre 15 miles away. On arrival, the woman underwent a CT angiogram, which demonstrated the small aortic puncture. She was transferred directly to vascular theatre, where she underwent an endovascular aortic stent graft. She was haemodynamically stable and waited 2 hours in theatre for a specialised endovascular aortic stent to arrive via courier from the depot. This was considered necessary because the grafts used in aortic aneurysm repair may not have an appropriate seal and may leak. After the operation, the woman was recovered in the intensive care unit. Following this minimally invasive approach, she made an excellent recovery, being discharged to the ward the same day and home the following day, avoiding the morbidity of a laparotomy.

Training

Adequate training in laparoscopic surgery leads to fewer complications, including vascular injuries. Lefebvre et al.[33] suggested the use of a hands-on mentor programme to

compensate for the reduction in training time among current registrar level surgeons. The objective is to provide an assessment of a trainee's performance with a structured debriefing, to encourage behaviour modelling and guide self-reflection from the trainee. This has been postulated to speed up the learning curve for laparoscopic skills and reduce complications.

Studies confirm that the use of a box-trainer simulator improves incremental acquisition of skills in, for example, intracorporeal suturing. It is encouraging for trainees to practise and rehearse using simulation training. Skill and confidence in laparoscopic suturing provides surgeons with additional options for the management of vascular injuries close to delicate organs, when the use of diathermy may harm organs in close proximity.[34] More high-fidelity models specifically for management of vascular injury are being developed. Although further study is needed to determine the best ways for them to be used, they are likely to become integrated into surgical training programmes in the future.

Evidence suggests that skills obtained in simulation training are applicable in real clinical scenarios. Simulation allows trainees to make mistakes, to ask the 'what if' questions, and to learn and reflect on such situations without risking patient safety.[35] As we work increasingly in teams, it follows that when teams rehearse and practise drills together, their clinical response will be more organised and efficient when they encounter a vascular injury.

Future developments

Newer haemostatic patches are becoming available on the market, such as the Veriset™ (Medtronic, Watford, UK) haemostatic patch. A randomised control trial in 2013 by Öllinger et al.[36] has shown proven benefit when the patch is used in either open or laparoscopic surgery for major hepatobiliary bleeding. The patch is taken out of its foil patch and placed directly on the bleeding vessel firmly for 30–60 seconds. Polymer components then cross-link, forming an impenetrable barrier that allows accelerative haemostasis to occur.

Other products are becoming available and are likely to offer alternative methods for managing injury to vessels in the near future.

Conclusion

Laparoscopic vascular injury is a serious and potentially fatal event. Prevention of injury involves the appropriate use of surgery, a good knowledge of anatomy and the safe use of abdominal entry techniques. Management of vascular injury depends on the vessel injured and the experience of the operating surgeon. Immediate stabilisation of the woman followed by appropriate involvement of a multidisciplinary team will minimise morbidity.

Contribution to authorship

KA and FS instigated and edited the article. GB researched and wrote the article. IA wrote and edited the article. DV edited the article. All authors approved the final version.

Disclosure of interests

FS is a senior Council Member and Chair of the Website and Digital Governance subcommittee for the British Society for Gynaecological Endoscopy. KA is a senior Council Member and is on the Awards and Bursaries committee for the British Society for Gynaecological Endoscopy. The other authors have no conflicts of interest.

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References

1 Querleu D, Chapron C, Chevalier L, Bruhat MA. Complications of gynecologic laparoscopic surgery: a French multicenter collaborative study. *New Engl J Med* 1993;**328**:1355.
2 Liu Y, Zhang X. Analysis of complications about gynecologic endoscopic procedures in 14 hospitals of Shanghai during 1992–2001. [Article in Chinese] *Zhonghua Fu Chan Ke Za Zhi* 2002;**37**:646–9.
3 Querleu D, Leblanc E, Cartron G, Narducci F, Ferron G, Martel P. Audit of preoperative and early complications of laparoscopic lymph node dissection in 1000 gynecologic cancer patients. *Am J Obstet Gynecol* 2006;**195**:1287–92.
4 Nordestgaard AG, Bodily KC, Osborne RW Jr, Buttorff JD. Major vascular injuries during laparoscopic procedures. *Am J Surg* 1995;**169**:543–5.
5 Hanney RM, Alle KM, Cregan PC. Major vascular injury and laparoscopy. *Aust N Z J Surg* 1995;**65**:533–5.
6 Becker S, De Wilde RL. Complications in gynaecological minimal access oncosurgery. *Best Pract Res Clin Obstet Gynaecol* 2016;**35**:63–70.
7 Bhoyrul S, Vierra MA, Nezhat CR, Krummel TM, Way LW. Trocar injuries in laparoscopic surgery. *J Am Coll Surg* 2001;**192**:677–83.
8 Querleu D, Chapron C. Complications of gynecologic laparoscopic surgery. *Curr Opin Obstet Gynecol* 1995;**7**:257–61.
9 Yuzpe AA. Pneumoperitoneum needle and trocar injuries in laparoscopy. A survey on possible contributing factors and prevention. *J Reprod Med* 1990;**35**:485–90.
10 Ahmad G, Gent D, Henderson D, O'Flynn H, Phillips K, Watson A. Laparoscopic entry techniques. *Cochrane Database Syst Rev* 2015;(8): CD006583.
11 Vilos GA, Vilos AG, Abu-Rafea B, Hollett-Caines J, Nikkhah-Abyaneh Z, Edris F. Three simple steps during closed laparoscopic entry may minimize major injuries. *Surg Endosc* 2009;**23**:758–64.
12 Teoh B, Sen R, Abbot J. An evaluation of four tests used to ascertain Veres needle placement at closed laparoscopy. *J Minim Invasive Gynecol* 2005;**12**:153–8.
13 Royal College of Obstetricians and Gynaecologists (RCOG). *Preventing Entry-related Gynaecological Laparoscopic Injuries*. Green-top Guideline No. 49. London: RCOG; 2008.
14 Richardson RE, Sutton CGJ. Complications of first entry: a prospective laparoscopic audit. *Gynecol Endosc* 1999;**8**:327–34.
15 Herrmann A, De Wilde RL. Adhesions are the major cause of complications in operative gynecology. *Best Pract Res Clin Obstet Gynaecol* 2016;**35**:71–83.

16 Tinelli A, Gasbarro N, Lupo P, Malvasi A, Tsin DA, Davila F et al. Safe introduction of ancillary trocars. *JSLS* 2012;**16**:276–9.
17 Cormier B, Nezhat F, Sternchos J, Sonoda Y, Leitao MM Jr. Electrocautery-associated vascular injury during robotic-assisted surgery. *Obstet Gynecol* 2012;**120**:491–3.
18 Ahlawat R. V1029. Intraoperative vascular injuries: inadvertent and preventable! *J Urol* 2012;**187** Suppl 4S:e418.
19 Zhu A, Yuan C, Piao D, Jiang T, Jiang H. Gravity line strategy may reduce risks of intraoperative injury during laparoscopic surgery. *Surg Endosc* 2013;**27**:4478–84.
20 Wong C, Merkur H. Inferior epigastric artery: surface anatomy, prevention and management of injury. *Aust N Z J Obstet Gynaecol* 2016;**56**:137–41.
21 Nezhat F, Brill AI, Nezhat CH, Nezhat A, Seidman DS, Nezhat C. Laparoscopic appraisal of the anatomic relationship of the umbilicus to the aortic bifurcation. *J Am Assoc Gynecol Laparosc* 1998;**5**:135–40.
22 de Rosnay P, Chandiramani M, Usman S, Owen E. Injury of epigastric vessels at laparoscopy: diagnosis and management. *Gynecol Surg* 2011;**8**:353–6.
23 Lam A, Khong SY, Bignardi T. Principles and strategies for dealing with complications in laparoscopy. *Curr Opin Obstet Gynecol* 2010;**22**:315–9.
24 Ludwig K, Scharlau U, Schneider Koriath S. Management of more frequent complications of laparoscopic surgery. Minimally invasive or always open surgery? [Article in German] *Chirurg* 2015;**86**:1105–13.
25 Simforoosh N, Basiri A, Ziaee S, Tabibi A, Nouralizadeh A, Radfar MH, et al. Major vascular injury in laparoscopic urology. *JSLS* 2014;**18**:e2014.00283.
26 Asfour V, Smythe E, Attia R. Vascular injury at laparoscopy: a guide to management. *J Obstet Gynaecol* 2018;**38**:598–606.
27 Guloglu R, Dilege S, Aksoy M, Alimoglu O, Yavuz N, Mihmanli M, et al. Major retroperitoneal vascular injuries during laparoscopic cholecystectomy and appendectomy. *J Laparoendosc Adv Surg Tech A* 2004;**14**:73–6.
28 Mechchat A, Bagan P. Management of major vascular complications of laparoscopic surgery. *J Visc Surg* 2010;**147**:e145–53.
29 Leonard M, Graham S, Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. *Qual Saf Health Care* 2004;**13** Suppl 1:i85–90.
30 Barbosa Barros M, Lozano FS, Queral L. Vascular injuries during gynecological laparoscopy: the vascular surgeon's advice. *Sao Paulo Med J* 2005;**123**:38–41.
31 Edwards S, Siassakos D. Training teams and leaders to reduce resuscitation errors and improve patient outcome. *Resuscitation* 2012;**83**:13–5.
32 Juarez-Soto A, Perez-Garcia M, Fuentes-Curtido M, Guisado-Martin C, Hernandez-Garrido M, Arrabal-Polo MA, et al. Vascular accident code: a security system in massive bleeding in laparoscopic urologic surgery. *Actas Urol Esp* 2016;**40**:597–600.
33 Lefebvre GG, Shore EM. Avoiding complications by a hands-on mentor programme. *Best Pract Res Clin Obstet Gynaecol* 2016;**35**:3–12.
34 Rosser JC, Rosser LE, Savalgi RS. Skill acquisition and assessment for laparoscopic surgery. *Arch Surg* 1997;**132**:200–4.
35 Agha RA, Fowler AJ. The role and validity of surgical simulation. *Int Surg* 2015;**100**:350–7.
36 Öllinger R, Mihaljevic AL, Schuhmacher C, Bektas H, Vondran F, Kleine M et al. A multicentre, randomized clinical trial comparing the Veriset™ haemostatic patch with fibrin sealant for the management of bleeding during hepatic surgery. *HPB (Oxford)* 2013;**15**:548–58.