Avoiding Major Vessel Injury During Laparoscopic Instrument Insertion

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- Blood vessel injuries

Laparoscopy is one of the most common surgical approaches performed in the United States today. This surgical approach has gained popularity compared with traditional laparotomy due to increased safety, better outcomes, and shorter recovery periods. Each year gynecologists and general surgeons perform an estimated 2 million laparoscopic procedures, including cholecystectomies, tubal ligations, appendectomies, hysterectomies, urogynecologic repairs, and cancer staging, to name a few.[1] Advances in laparoscopic technology and the development of robotic surgery are likely to further increase the number of cases performed laparoscopically. Fortunately, major complications related to laparoscopy are uncommon, occurring in less than 2% of procedures.[2]

One of the most serious laparoscopic complications is injury to major vessels, which reportedly occurs in approximately 0.04% of cases.[3] Vessel injury occurs most commonly while gaining intra-abdominal access during insertion of the Veress needle and port trocars through the abdominal wall.[2,4] Although vessel injury occurrence is low, mortality is high. Injury to one or more major vessels can quickly result in fatal exsanguinations, with a majority of these deaths occurring within the first 24 hours

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of surgery.[1] Despite decades of research and development in an effort to create safer instruments, the incidence of these injuries has not decreased.[2,4]

The purpose of this article is to review recommended methods for avoiding major vessel injury while gaining laparoscopic access. A first step is to review the anatomic relationships of abdominal wall landmarks to the major retroperitoneal vessels. Because Veress needles are commonly used to insufflate the abdomen before trocar placement, methods for their successful placement are reviewed. Various methods and locations for primary trocar placement are compared. Finally, methods to avoid vessel injury during placement of secondary ports are described.

MAJOR VESSELS AT RISK DURING LAPAROSCOPY

Major Vessels of the Lower Abdomen and Pelvis

The major arteries that lie in the retroperitoneal space of the lower abdomen and pelvis include the descending aorta, the common iliac arteries, and the external and internal iliac arteries (**Fig. 1**).[5] At the bifurcation, the common iliac arteries diverge bilaterally. Near the pelvic brim, the internal iliac artery branches off dorsally, and the external iliac artery continues caudally to enter the inguinal canal. The inferior epigastic vessels arise from the external iliac arteries and ascend upward through the tranversalis fascia and then between the rectus abdominis and the posterior lamellar sheath.

Analogous venous vessels include the inferior vena cava, common iliac veins, and their internal and external branches. The major veins lie dorsal to these arteries in the lower abdomen and pelvis. Analogous to the arteries, the vena cava bifurcates

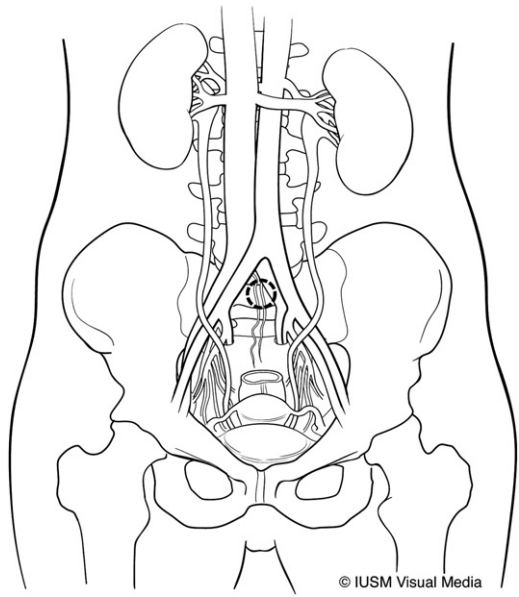

Fig. 1. Location of the major vessels in relation to the umbilicus and pelvic bones. The average location of the umbilicus below the aortic bifurcation is indicated by a dashed circle. The major tributaries of the vena cava (ie, the common, internal, and external iliac veins) lie dorsal and medial to the major branches of the aorta (ie, the common, internal, and external iliac arteries). (*From* Sandadi S, Johannigman JA, Wong V, et al. Recognition and management of major vessel injury during laparoscopy. J Minim Invasive Gynecol, 2010, in press; with permission.)

into the common iliac veins. The internal and external iliac veins lie dorsal and medial to the corresponding arteries.

Common Major Vessel Injuries

Injuries during laparoscopic entry have been reported to every major vessel in the pelvis. The relative frequency at which major retroperitoneal vessels are injured during laparoscopy is difficult to determine for several reasons. The first reason is that major vessel injuries are uncommon. In addition, the number of major vessel injuries is higher than the reported number because many major vessel injuries are never reported. It is also likely that fatal major vessel injuries are more likely to be reported.

Despite these limitations, review of 75 published injuries in three small series can give some idea of the vessels at greatest risk of injury during laparoscopy.[1,6,7] A notable aspect of these data was that arterial injuries made up 75% (56/75) of the total: 25% involved the aorta and 21% the right common iliac artery. The remaining 29% of these arterial injuries were distributed between the left common iliac artery and the left or right external or internal iliac arteries. The vena cava was injured in 11% (8/75). All other venous injuries were accompanied by injury of the corresponding overlying artery. Although the side of iliac vessel injury was only specified in 30 cases, 73% (22/30) of these injuries occurred on the right.

The large number of aorta and vena cava injuries was surprising, because these vessels lie at or above the umbilicus in most women.[8] Injuries to these vessels are likely to result from inserting periumbilical instruments at angles greater than 45° from the plane of the spine. The preponderance of right iliac vessel injuries might reflect a tendency of surgeons standing on the left side of patients and inserting instruments with the right hand to place instruments in a direction deviated slightly to the right of midline.

AVOIDING MAJOR VESSEL INJURY DURING LAPAROSCOPIC ENTRY

Insertion of the Veress needle and primary trocar for initial entry remains the most hazardous part of laparoscopy, accounting for 40% of all laparoscopic complications and the majority of the fatalities.[1] Despite decades of research and development to find safer methods for initial laparoscopic entry, major vessel injuries have been reported using virtually all types of trocar insertion methods.[9]

The first modern laparoscopic entry techniques used to gain laparoscopic access used a periumbilical insertion site and were categorized as closed or open. The traditional closed technique involves blind placement of a Veress needle and sharp primary trocar, whereas the open technique is performed by placing a blunt trocar through a minilaparotomy incision. Other techniques that have been developed include direct trocar insertion (a closed technique where the primary trocar is inserted before peritoneal insufflation), left upper quadrant (LUQ) insertion (where an alternate insertion site is used), and the use of innovative trocar designs. Some of the most commonly reported methods are compared.

Closed Laparoscopy: Veress Needle and Primary Trocar

The majority of retroperitoneal vessel injuries during laparoscopy occur during blind placement of the Veress needle or primary trocar through a periumbilical incision.[4] To minimize this risk, surgeons should have an accurate understanding of the anatomy of the lower abdomen and pelvis.[10]

Traditionally, the primary site of entry into the abdomen is located in the midsagital plane at the lower margin or base of the umbilicus. This location was originally chosen

for cosmetic and safety reasons. There are no major blood vessels in the midline of the pelvis because the aorta and vena cava bifurcate near the umbilicus. Thus, placing the Verres needle and primary trocar through the umbilicus directed toward the pelvis was found to be safe.[11] This safety depends, however, on appropriate direction and angle of insertion.

Direction of insertion

The umbilicus is an excellent anatomic landmark to determine the midline. Instruments placed through the umbilicus must be inserted, however, in a direction parallel to the long axis of the patient so that their sharp tips remain in the midline. A deviation of as little as 20 mm from parallel places an instrument tip almost 4 cm from the midline.

To minimize the risk of major vessel injuries when placing instruments through the umbilicus, every effort must be made to keep the direction of insertion in the midline. Unfortunately, the long axis of a patient can be difficult to estimate after the patient has been covered in drapes. The propensity of right-sided major vessel injuries (described previously) is probably related to this difficulty.

Angle of insertion

A second variable to consider when inserting laparoscopic instruments through the umbilicus is the angle of insertion. Based on the location of the major vessels and their bifurcations, the standard approach in the early years of laparoscopy was to place the Veress needle and primary trocar through the umbilicus 45° from the horizontal plane of a patient's spine.[12] It became apparent, however, that in obese patients, instruments inserted at this angle would often not enter the peritoneal cavity. For this reason, some surgeons recommended inserting instruments at 90° from the horizontal plane in obese patients[13] and other surgeons recommend this angle in all patients.[9]

An anatomic study subsequently illustrated that the anatomy of the abdominal wall changed greatly with weight and thus the angle of insertion should be modified accordingly (**Fig. 2**).[10] For practical purposes, women can be divided into nonobese (includes normal weight and overweight) and obese categories. Nonobese women have a body mass index less than or equal to 30 kg/m^2, whereas obese women have a body mass index greater than 30 kg/m^2, which corresponds to a weight greater

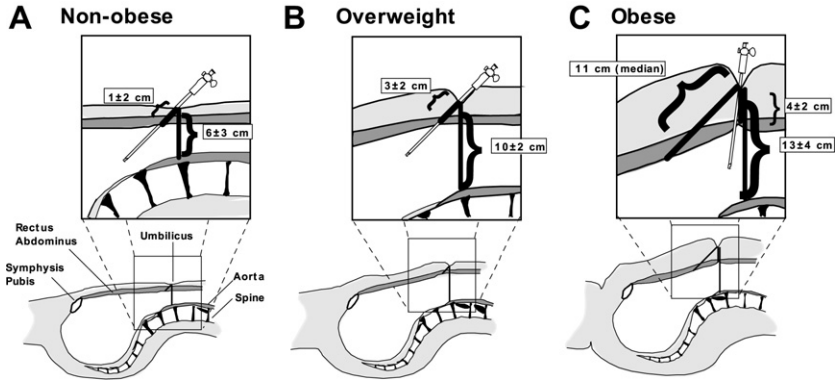

Fig. 2. Changes in the anatomy of the anterior abdominal wall based on weight. (*From* Hurd WW, Bude RO, DeLancey JO, et al. Abdominal wall characterization with magnetic resonance imaging and computed tomography. The effect of obesity on the laparoscopic approach. J Reprod Med 1991;36:473–6; with permission.)

than 91 kg (>200 lb). The ideal angles of insertion based on weight are based on these data.

In nonobese women, it is recommended that instruments be inserted through the umbilicus at 45° from the horizontal plane of a patient's spine. At this angle, the abdominal wall thickness in nonobese women ranges from an average of 2 to 3 cm; thus, successful intraperitoneal placement of instruments is highly likely (see **Fig. 2**A, B). This angle is also likely to minimize the risk of major vessel injury, because the distance from the skin to these vessels at 90° averages only 6 to 10 cm and can be as close as 2 cm in slender patients. In addition, the aortic bifurcation is often at or caudal to the level of the umbilicus in nonobese patients.[8]

In obese women, it is recommended that instruments be inserted through the umbilicus closer to 90° from the horizontal plane of a patient's spine. At 45°, the abdominal wall thickness in obese women is often greater than 11 cm, making successful intraperitoneal placement unlikely (see **Fig. 2**C). Fortunately, the distance from the skin to these vessels at 90° averages greater than 13 cm, and the aortic bifurcation is almost always cephalad to the level of the umbilicus in obese patients.[8]

To place instruments through the umbilicus at the proper angle, it is important to be aware of a patient's position in relation to horizontal.[6] Most laparoscopic surgery is performed in the Trendelenburg position (feet higher than the head) to keep bowel away from the operative field in the pelvis. If a patient is placed in Trendelenburg position with the feet elevated 30° relative to the head before instrument insertion, instruments inserted at 45° from horizontal are placed at 75° from the horizontal plane of the patient's spine. This is likely to increase the risk of major vessel injury, particularly in slender patients.[6] For greatest safety, surgeons should make sure they are aware of a patient's position in relation to horizontal before laparoscopic instrument placement.

High-pressure entry

Another technique used in conjunction with closed laparoscopy in an effort to decrease the risk of major vessel injury is high-pressure entry. Rather than inserting the primary umbilical trocar after obtaining intra-abdominal pressure of 18 to 20 mm Hg, many surgeons increase the pressure to 25 to 30 mm Hg. The rationale is to make the anterior abdominal wall stiffer such that the downward pressure exerted by trocar insertion does not decrease the distance of the umbilicus to the retroperitoneal vessels.[14] Although no controlled studies large enough to demonstrate an advantage have been published, large series, including more than 8000 cases, suggest that the risk of major vessel injury using this technique is approximately 1 in 10,000 cases (0.01%) compared with a risk of 4 in 10,000 cases (0.04%) reported using standard pressures.[13,14]

Verify location of Veress needle tip

A Veress needle is used to insufflate the peritoneal cavity before trocar insertion by the majority of gynecologists.[15] One disadvantage of using a Veress needle is that it dramatically increases the risk of intravascular insufflation and venous gas embolism, a rare complication of laparoscopic entry, reported to occur in approximately 1 in 100,00 cases.[16]

To prevent intravascular insufflation when using a Veress needle, it is recommended that efforts be made to verify that the tip of the needle is located in the peritoneal cavity before insufflation.[2] The following maneuvers have been proposed minimize the risk of intravascular insufflation.

- The Veress needle value should be open when the needle is inserted. Spontaneous egress of fresh blood through the needle indicates that the tips had entered an artery.
- The double-click test. A surgeon should feel or hear two clicks as a Veress needle is placed through the abdominal wall. The retracted blunt needle tip will suddenly extend after it passes through the anterior rectus abdominus fascia and again when it enters the peritoneal cavity.[2]
- The waggle test. The hub of the Veress needle should move freely about a fulcrum point located within the anterior abdominal wall. Lack of free movement suggests that the needle tip has entered an intraperitoneal or retroperitoneal structure and the needle should be partially withdrawn. Opponents of this maneuver point out that, if done forcefully, it is likely to enlarge an injury to a fixed vessel or viscus.[17] It is also likely, however, to alert surgeons to the possibility of retroperitoneal placement before insufflation.
- The aspiration test. The Veress needle should be aspirated with a 5-mL syringe after placement. Aspiration of fresh blood fresh blood through the needle suggests that the tips had entered a vein.[2]
- The drop test. A drop of saline is placed in the opened hub of the Veress needle, and the abdominal wall is lifted. If the drop is drawn into the hub, it is likely that the needle tip is in the abdominal cavity.[18] If not, it might suggest that the location of the needle tip is preperitoneal (most likely), retroperitoneal, or within a viscus.

It is recommended that one or more of these methods be used when placing a Veress needle into the abdomen.[18] None of these methods, however, absolutely assures intraperitoneal placement of the needle tip, and it is unlikely that any of them can completely prevent intravascular insufflation. Once insufflation is begun, the strongest predictor of intraperitoneal placement seems to be an initial filling pressure of less than 10 mm Hg.[19]

Open Laparoscopy

Open laparoscopy is the most widely used alternative technique for placement of the primary laparoscopic port. The Hasson technique is fundamentally a minilaparotomy incision followed by placement of the primary port directly into the peritoneal cavity.[20] This avoids the blind placement of the Veress needle and sharp trocar. Instead, the periumbilical fascia is incised with a scalpel or scissors, the peritoneum entered bluntly, and the primary port is placed into the peritoneal cavity using a blunt trocar.

Open laparoscopy has been demonstrated to decrease, but not completely prevent, the risk of major vessel injury.[21] Although early studies suggested that the open technique completely avoided major vessel injuries, subsequent studies found that the open technique decreased the rate of vascular injury to 0.01% compared with a rate of 0.04% associated with closed techniques using a Veress needle.[3] To date, no case of intravascular insufflation has been reported using an open technique. Most gynecologists continue to use a closed technique, however, because major vessel injury remains rare and large studies have not demonstrated a decreased risk of bowel injuries using the open technique.[22]

Other Laparoscopic Entry Methods

Multiple insertion methods and instruments have been developed in the past 20 years in an effort to decrease the risk of trocar complications, most notably injuries to bowel or major blood vessels. Each method seems to have theoretic advantages compared

with the traditional closed and open techniques. None, however, seems to have completely eliminated the risk of major vessel injury.

Direct trocar insertion

Direct trocar insertion is a laparoscopic entry technique wherein the primary trocar is placed without prior insufflation.[23] The advantages of direct trocar insertion are that this technique is slightly faster than standard closed laparoscopy and avoids the risks of Veress needle placement. For this technique, the primary trocar is inserted though the umbilicus, with or without elevation of the anterior abdominal wall manually or with towel clips.[24]

Although no controlled studies of direct trocar insertion have been published that are large enough to demonstrate the relative risk of major vessel injury, it seems that this technique might actually increase this risk. Larger series, including more than 10,000 cases, suggest a risk of major vessel injuries in the range of 0.06% to 0.09% of cases compared with a risk of 0.04% of cases reported using a standard closed technique.[3,25,26] This observation is not surprising. If high pressure abdominal insufflation resists downward pressure exerted by trocar insertion and helps maintain the distance of the umbilicus to the retroperitoneal vessels, it makes sense that no abdominal insufflation might increase the risk of the trocar tip coming into contact with retroperitoneal structures.[14] This apparent increased risk of major vessel injury might be one reason why direct trocar insertion is one of the least frequently used techniques by gynecologists.[3]

Left upper quadrant insertion

Insertion of the Veress needle and primary trocar through a site in the LUQ is recommended by some surgeons to decrease the risk of complications associated with bowel adhesions in women with prior abdominal surgeries.[27,28] The LUQ insertion site (Palmer point) is located 3 cm below the middle of the left costal margin, and instruments are routine inserted perpendicular to patients' skin.[29]

The risk of major vessel injury using the LUQ technique remains uncertain. No major vessel injuries have been reported to date, at least in part because to date fewer than 2000 cases using this technique have been published. Anatomic studies indicate that the abdominal wall is uniformly thin in this location and the distance from the skin to the retroperitoneal structures is greater than 11 cm in most patients.[30] Because this distance can be less than 7 cm in many slender patients, however, it is recommended that instruments placed through the Palmer point in slender patients be directed 45° caudally in relation to a patient's spine.[30]

Alternative primary trocars

Multiple innovative primary trocars have been developed over the past 20 years in an effort to decrease entry complications. Most notable among these are shielded disposable trocars, optical trocars, and radially expanding trocars.[31–33] Although studies of these methods have not demonstrated a dramatic increase in complications compared with the traditional closed technique, major blood vessel injuries seem to remain a risk of primary trocar insertion.[2,34] Published controlled studies have uniformly been underpowered to determine the relative risk of major vessel injures associated with these techniques because of the rarity of these events. Thus, there is currently no evidence of benefit of one technique or instrument over another in terms of preventing major vascular injury.[2,35]

AVOIDING VESSEL INJURY DURING SECONDARY PORT TROCAR PLACEMENT

Initial Insertion of Secondary Ports

Major vessel injuries can also occur during placement of secondary ports, in particular those placed lateral to the midline.[36] Secondary trocars are usually placed 5 cm superior to the midpubic symphysis and 8 cm lateral to the midline in an effort to avoid injury to vessels in the anterior abdominal wall.[37] Unfortunately, this location is often directly over the external iliac vessels. For this reason, great care must be taken when inserting trocars in this location to avoid major vessel injuries. The following methods are based on anatomic data and clinical experience, but none has proved to decrease the risk of major vessel injury.

It is well appreciated that it is important to laparoscopically visualize the tip of secondary trocars during placement.[36] This presupposes that trocars are always placed under ideal control, however. In practice, the variation in density of the abdominal wall layers and trocar protective mechanisms can result in sudden loss of resistance accompanied by unexpectedly vigorous and deep trocar insertion. For this reason, measures should be taken to control direction, depth, and speed during secondary trocars insertion.

Direction

The direction of insertion of secondary port trocars is determined by abdominal wall anatomy and the proximity of underlying structures. Secondary trocars are inserted as close a possible to perpendicular to the abdominal wall and underlying peritoneum for two reasons. First, it is often difficult to penetrate the peritoneum obliquely, and second, oblique placement toward the midline can injure abdominal wall vessel, even when the insertion site is well lateral. In this direction, however, the tip of a lateral port trocar is often pointed directly at the external iliac vessels. For this reason, once the trocar tip has penetrated the peritoneum, the direction of insertion should be changed medially away from these vessels.

Depth

The depth of insertion of secondary port trocars should be limited. The goal is to place the trocar sleeve completely through the abdominal wall peritoneum. Excess depth of insertion is one of the common causes of trocar injuries and is often related to uncontrolled thrust of the trocar into the abdomen after an unexpected loss of resistance.[38] To stop a trocar's forward progress as soon as it has penetrated the peritoneum, it is recommended that surgeons consciously balance the force of the agonist muscles, which produce forward thrust, with the antagonist muscles, which stop it.[38] In the event of an unexpected loss of resistance, the subsequent depth of insertion can also be limited either by extensions of the index finger on the inserting hand or by using a two-hand insertion technique where the second hand grasps the sleeve near the skin.

Speed

Speed of insertion is the final parameter that can be controlled during secondary port placement. To minimize the risk of injury, trocars should be inserted slowly rather than quickly even when there is adequate distance between the compressed abdominal wall and the nearest major vessel.[38] This is particularly important when the distance between the emerging trocar tip and major vessels (or bowel) is limited, so that the retracting blade or extending shield found in many modern trocars can deploy. When trocars without such devices are used, controlled speed allows redirection of the emerging trocar tip away from vital structures (discussed previously).

Reinsertion of Secondary Ports

Major vessel injury can also occur during reinsertion of secondary trocars, particularly when the pneumoperitoneum has been lost.[38] Port reinsertion is required when a port has inadvertently been removed from the peritoneal cavity or when a smaller (5-mm) sleeve must be replaced with a larger (10–12 mm) sleeve for specimen removal. The risk of vessel injury can be almost completely avoided by not using a sharp trocar for reinsertion. There are several possible methods that can be used for this purpose.

A safe method for reinserting a port without using a trocar is to place a laparoscopic instrument (eg, blunt probe or grasper) through the port and into the incision and locating the fascial and peritoneal incisions by gentle probing. Once located, the sleeve can be slid over the instrument, much the same way that a catheter is advanced over a guide wire for placement of a central line into a deep vessel.[11]

Another method for reinsertion of the same-sized port or larger back into an existing port site is by using a blunt trocar.[39] Although specially designed blunt trocars were used for this purpose in the past, several modern trocar designs allow for the blade to be retracted into blunt conical blade guard before reinsertion of the sleeve into the abdomen.

SUMMARY

Laparoscopy offers patients a minimally invasive approach to common gynecologic procedures. It has become an accepted approach for most gynecologic problems. Laparoscopic surgeons should have a thorough understanding of the anatomy of the lower abdomen and pelvis. Although vessel injuries remain rare complications of laparoscopic surgery, surgeons should use techniques that can decrease the risk of these injuries so that patients can enjoy the benefits of minimally invasive surgical techniques.

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