FLS Module 2: Intraoperative Considerations

* Anesthesia and Patient Positioning
  + Local Anesthesia
    - Indication: diagnostic laparoscopy, Tubal ligation, Select inguinal hernia repairs
    - Agents: Bupivacaine, Ropivacaine, Lidocaine
  + Regional Anesthesia
    - Epidural may be used alone or as an adjunct to general anesthesia to provide improved muscle relaxation, postoperative analgesia, and decreased postoperative ileus
  + General Anesthesia
    - Premedication with benzodiazepine (anxiety/amnesia), atropine/glycol, pyrrolate (prevention of arrhythmia in response to insufflation, preferable to use intraoperatively), H2 blocker/sodium citrate (minimize aspiration), daily meds
    - Anesthetic agents
      * IV induction
      * ET intubation for intermittent positive pressure ventilation
      * Neuromuscular blockade
    - Use of LMA is controversial in laparoscopy
* Patient positioning
  + Supine
    - Arms dictated by procedure (tucked for lower abdomen/pelvis, abducted for upper abdomen/chest)
    - Arms should not be abducted more than 90 degrees (brachial plexus stretch injury)
    - Arms should be carefully padded to avoid pressure injury
    - Hands should be positioned away from breaks in the table
  + Reverse Trendelenburg
    - Footboard to prevent sliding, Safety band to prevent knees from buckling
  + Lithotomy
    - Allen stirrups preferable to candy cane stirrups
    - Knees should be level with the torso
  + Lateral decubitus
    - Care to avoid stretch of the brachial plexus (Role placed under dependent axilla, upper arm placed in sling or lain on padded surface)
    - Bean bag edges must not extend past the midline anteriorly or posteriorly, can become stiff (risk for pressure injuries) when air is suctioned out
    - Access to adrenal gland/kidney:
      * OR table flexed enough to increase the distance between the costal margin and the iliac crest (optimal access)
    - Modified decubitus allows alteration between lateral decubitus and supine (pt must be properly secured)
      * Splenectomy, nephrectomy, adrenalectomy
* Pneumoperitoneum establishment and Trocar placement
  + Closed technique: Veress needle (or Visiport)
    - Veress: Spring loaded needle, cylindrical sharp outer hollow needle, blunt tipped inner portion is conduit for insufflation gas
    - Small incision through skin and subcutaneous tissue
    - Elevate abdominal wall to create safe distance between anterior peritoneum and retroperitoneal vascular structures
    - Veress needle passed through layers of abdominal wall until no resistance is felt, tip should be freely mobile
    - Intraperitoneal check:
      * Loss of resistance with insertion
      * Audible click as inner blunt, spring-loaded trocar releases
      * Freely mobile tip
      * No aspiration of blood or enteric contents
      * Low insufflation pressure with low to medium flow
      * Free flow of saline
      * Hanging drop test
      * Tympany with percussion of abdomen after insufflation
    - Insertion of initial trocar
      * Reconfirm needle tip position and relaxation
      * Enlarge incision if needed
      * Keep wrist straight, combine twisting pushing motion
      * Relative contraindication to blind trocar insertion:
        + Previous abdominal surgery
        + Previous intra-abdominal inflammatory process
      * Absolute contraindication to blind trocar insertion
        + Abdominal scar from prior open operation in immediate vicinity of trocar insertion
        + Through previously placed intraperitoneal mesh for hernia repair
    - Inspect for injury
    - Complications of Veress Needle Insertion (inc pneumoperitoneum)
      * Bowel injury
      * Mesenteric or omental vascular injury
      * Retroperitoneal vascular injury
      * Cardiac arrhythmia
      * Hypotension
      * High airway pressures
      * Pneumothorax
      * Gas embolism
  + Open technique: Hasson Trocar
    - Should be used if there are concerns regarding adhesive disease (scars, hernias)
    - Perform with caution, away from previous scar
    - Less likely to have undetected inadvertent organ injury, although still possible
    - Most common trocar: Blunt tipped
    - Dissect to the fascia, elevate and incision fascia, place anchoring sutures (2-0 or 0 delayed absorbable suture)
    - Dissect through preperitoneal fat, elevate and incise the peritoneum, place blunt tipped trocar and secure with anchoring sutures
    - Inspect for injury
  + Establishing pneumoperitoneum
    - Pneumoperitoneum should be 10-15 mmHg (1-3L CO2)
  + Additional Trocars
    - Select appropriate location in relation to operative site and monitor
    - Locate exact peritoneal entry site with palpation or a finder needle
    - Use “in line” grip with wrist straight and parallel to trocar shaft
    - Direct laparoscopic visualization
    - Place away from epigastric vessels
* Physiology of pneumoperitoneum
  + Most common insufflation gas: Carbon dioxide
    - Rapidly absorbed
    - Easily eliminated
      * Diffusion coefficient is 20x that of oxygen – making it highly soluble in blood and easily transported to the alveoli for expiration
    - Suppresses combustion
    - Readily available
    - Relatively inexpensive
  + Chemical effects
    - Increase in arterial CO2 concentration
    - Increase in end tidal CO2
    - Decrease in serum pH
    - Greatest change in first 15-20 minutes, then obtains steady state after 1 hour
    - Cardiovascular:
      * Systemic vascular changes
      * Cerebral auto-regulation of blood flow
      * Vagal responsiveness to reverse Trendelenburg position
  + Pressure effects
    - Cardiovascular
      * Lower initial insufflation rate and set pressure associated with slightly less postoperative and shoulder pain
    - Pulmonary
      * Increase minute ventilation to eliminate absorbed CO2
      * Reduced functional residual capacity (FRC)
      * Increase peak airway pressure
      * Reduced pulmonary compliance
    - Renal
  + Monitoring during pneumoperitoneum for pressure/chemical effects
    - Cardiac rhythm
    - Pulse oximetry
    - End tidal CO2 (increased) – essential in pts with severe cardiopulmonary disease
    - Heart Rate
    - Blood Pressure
    - Urine Output
* Alternatives to CO2
  + Nitrous oxide
    - Benefits:
      * Less acid-base disturbance
      * Increased tolerance of pneumoperitoneum without general anesthesia
      * Less postoperative pain
      * May be better tolerated in patients with severe cardiopulmonary disease
    - Risks: Does not suppress combustion. Fire hazard if using electrocautery in the presence of open bowel (supports combustion)
  + Air
  + Inert gases: Helium/Argon
    - Benefits: Eliminate hypercarbia and acidosis
    - Risks: Less soluble in blood 🡪 increases risk of extraperitoneal gas extravasation (embolism)
* Cardiovascular Changes with Pneumoperitoneum
  + Increased preload
  + Increased afterload
  + Decreased cardiac output (and decreased cardiac index)
  + Cardiac Output Response:
    - Variable amongst individuals
    - Hypercarbia
      * Influenced by the body’s buffer system, pulmonary system, extraperitoneal insufflation
    - Decreased cardiac output
      * Exacerbated by reverse Trendelenburg position, hypovolemia
      * Changes exacerbated by underlying cardiac disease
      * May cause reduced tissue perfusion 🡪 hypotension, cardiac arrhythmia, decreased urinary output, increased end tidal CO2
    - Prevention of decreased cardiac output:
      * Pt should receive all prescribed cardiac medications on the morning of surgery
      * Well hydrated, especially if pt underwent bowel prep
    - Intraoperative hypotension:
      * Desufflate immediately
      * Check insufflator settings and function
      * Check for adequate relaxation
      * Check intravascular volume status
      * Check for other causes of hypotension (bleeding)
  + Cardiac arrhythmias due to pneumoperitoneum
    - Bradycardia
    - PVCs
    - Sinus tachycardia
      * Vagally mediated
      * Occurs soon after pneumoperitoneum is established (use low flow rates and keep pressures low)
  + Increased Vena Cava Resistance
    - Reduce lower extremity venous flow rate
    - Risk of VTE
      * Procedure specific: Duration > 1 hour, Pelvic procedures
      * Patient specific: History, age, immobility, varicosities, cancer, renal failure, obesity, peripartum status, CHF, MI, HRT, OCP, Multiparous, IBD, Infection
* Renal Effects of Pneumoperitoneum
  + Urine production is an unreliable measure of volume status during laparoscopy
  + Increased intraabdominal pressure 🡪 decreased renal blood flow 🡪 decreased filtration 🡪 decreased urine output
  + Secondary release of renin and ADH 🡪 Na and free water reabsorption 🡪 oliguria
  + Intraoperative oliguria is common
  + Postoperative oliguria usually resolves within a few hours
  + Persistent oliguria warrants close monitoring and may require further investigation
* Additional considerations
  + Hypothermia (Higher risk with longer cases)
    - Use of warmed CO2 for insufflation 🡪 statistically different body temperatures, not clinically significant
    - Prevention:
      * Warmed IV fluids
      * Forced air body surface warmer
      * Warm room temperature
      * Warm irrigation fluid
  + Extraperitoneal gas extravasation
    - Intentional
    - Subcutaneous
    - Thoracic
    - Delayed CO2 toxicity
    - Gas embolus (rare, <1% of cases)
      * Small, asymptomatic emboli occur frequently (not clinically significant)
      * Symptomatic emboli are rare (0.015%), manifest by sudden cardiovascular collapse
      * Diagnosis:
        + Severe hypotension
        + Jugular venous distension
        + Tachycardia
        + Mill wheel murmur (loud, machinery-like, churning or splashing sound due to blood mixing with air in the right ventricle, best heard over the precordium)
        + Rule out other sources of hypotension (bleeding, pneumothorax, primary cardiac failure)
      * Treatment:
        + Place in Trendelenburg, left side down
        + Rapid fluid administration
        + Central line placement to evacuate or break up embolus in right heart chambers
  + Equipment concerns
    - Filter to protect insufflator
    - Use clean tubing
    - Keep cylinder upright to avoid liquid CO2 from escaping
    - Risk of contamination: Prevention
      * Aerosol
        + Smoke evacuation and filtration devices
        + Evacuation of pneumoperitoneum at end of case into suction canister
      * Sharps – standard management
      * Standard personal protection
* Exiting the Abdomen
  + Ensuring hemostasis with final abdominal inspection
  + Reduce pneumoperitoneum pressure to inspect for venous ooze
  + Common causes of unrecognized bleeding:
    - Trocar injury of abdominal wall vessels
    - Injury to vessels or organs away from the operative field
    - Tamponade of venous bleeding
  + Placement of drains
    - May pull through 5mm port site with grasper
    - May push through 10/12 port
    - Clamp drain tubing to prevent loss of pneumoperitoneum
  + Active resolution of pneumoperitoneum
  + Port site closure
    - 5mm port sites (or smaller) do not require fascial closure
    - Fascial closure:
      * Open technique
      * Laparoscopic assisted technique (Endoclose, Carter Thompson, Keith needle)
      * Completely laparoscopic technique (visualization of fascia is poor)

**MODULE 2 SCRIPT**

**Module 2 – Intraoperative Considerations 🡪 Anesthesia and Patient Positioning 🡪 Type of Anesthesia:**

1. Although local anesthesia can be used to prevent parietal pain at trocar sites, there is no conclusive evidence that a local anesthetic will prevent the visceral pain associated with either the pneumoperitoneum or manipulation and dissection of the viscera. However, local anesthesia for certain laparoscopic procedures may be a good choice in selected patients such as diagnostic procedures, tubal ligation, and selected inguinal hernia repairs.
2. Epidural anesthesia may be used as an adjunct to general anesthesia in selected operations to provide improved muscle relaxation, post-operative analgesia, and decreased duration of post-operative ileus. As with local anesthesia, epidural anesthesia may be used alone in selected cases.
3. General anesthesia is used for the vast majority of patients undergoing a general laparoscopic procedure. Pre-medication with a benzodiazepine may be given to ease anxiety and cause amnesia. Although preoperative prophylactic atropine may prevent brady-arrhythmias caused by the pneumoperitoneum, it also causes excessive dry mouth, so it is preferable to use atropine or glycopyrrolate intraoperatively and only if needed.
4. Other preoperative medications are usually used in patients undergoing general anesthesia. Patients should receive acid reducing therapy such as an H2 blocker or a non-particulate antacid such as sodium citrate which should minimize the effects of aspiration should it occur. Medications taken for chronic medical problems should be taken in accordance with the institution standard and are not different for laparoscopic or open surgery.
5. There is no consensus about which agents to use as a general anesthetic for a laparoscopic procedure, but some basic principles are uniformly accepted. Intravenous induction and endotracheal intubation for positive pressure ventilation and neuromuscular blockade are important. The use of a laryngeal mask airway during laparoscopy is controversial. Bowel distension with the use of inhaled nitrous oxide is rarely a problem with a possible exception in patients with bowel obstruction.

**Module 2 – Intraoperative Considerations 🡪 Anesthesia and Patient Positioning 🡪 Patient Positioning:**

1. The success of most laparoscopic procedures, will, at least in part, be dependent upon the ability of the surgical team to manipulate the position of the patient with the operating table. The table should raise or lower, flex in the middle, tilt head up or head down, and tilt left or right. Changing the position of the patient allows gravity to improve the view of the operative field by vacating surrounding organs. Care should be taken to make sure the patient does not slide with position changes before prepping and draping. Additionally, it is important to take all appropriate precautions to avoid positioning injuries such as proper padding.
2. With the patient supine on the table, the position of the arms will be dictated by the nature of the procedure and the locations where the surgeon and assistants stand. For surgical procedures in the pelvis and lower half of the abdomen, it is helpful to tuck one or both arms at the side of the patient to provide more room for the surgeon and assistants to position themselves. For surgical procedures in the upper abdomen, the arms may be left out to the side; that is, with the shoulder abducted to a 90-degree angle. But care should be taken to ensure that the arm is not abducted more than 90 degrees to avoid a brachial plexus stretch injury. Arms must also be carefully padded to prevent pressure point injury. The arm position should be checked frequently during surgery. Any time the arms are tucked, make sure the hands are not near a break in the table. This will avoid hand injury if the table is flexed during the operation.
3. If the use of steep reverse Trendelenburg is anticipated, a footboard may prevent the patient from sliding. Additionally, a belt should be placed across the patient’s thighs to prevent the knees from buckling during the procedure.
4. When utilizing the lithotomy position for any laparoscopic procedure, care must be taken to properly fit the positioning equipment to the patient rather than making the patient fit the positioning equipment. Sequential compression devices should reduce the incidence of complications and DVT formation. Allen stirrups or split leg table are preferable to candy cane stirrups due to less extreme angulation and ability to conform to individual patient needs. This is particularly important for longer procedures. For procedures that also require dissection in the upper abdomen, such as omentectomy and colon resection, it is important to keep the knees level with the torso to avoid interference with the handles of the laparoscopic instrumentation.
5. In the decubitus position, additional care must be taken to avoid stretch in the brachial plexus on both sides. A roll placed in the axilla of the dependent side of the patient can protect both the axilla and the brachial plexus on that side while the upper arm must be held in a sling or laid on a padded surface for adequate support. A bean bag may be helpful to hold the patient at exactly the correct angle, but the edges of the bag must not extend past the midline either anteriorly or posteriorly so as to avoid interference with port placement and instrument manipulation. Additionally, a bean bag that has the air suctioned out is more rigid than pillows and blankets and may increase the risk of injury for longer operations. Padding the bean bag may reduce this risk. For access to the adrenal gland and kidney, the OR table should be flexed enough to increase the distance between the costal margin and the iliac crest. This provides more space through which ports can be placed for optimal access to the target organ.
6. Additionally, a modified decubitus position can be used to allow rotation of the operating table to alternate between a full lateral decubitus and supine position. It is important to adequately secure the patient to the table taking all appropriate precautions to avoid slippage and neuromuscular injury. This allows the exposure benefits offered by the lateral decubitus position while maintaining the ability to quickly change to the supine position in the event that conversion to open surgery is required. This may avoid the use of a flank incision, which may not be tolerated as well as a subcostal or midline incision. Another benefit of this positioning flexibility is for the extraction of larger specimens. Procedures that commonly use this positioning include splenectomy, nephrectomy, and adrenalectomy.

**Module 2 – Intraoperative Considerations 🡪 Pneumoperitoneum Establishment and Trocar Placement:**

Establishment of the pneumoperitoneum is the first step in a laparoscopic procedure unless an abdominal wall lift is used. The pneumoperitoneum may be established either using the closed technique of a verses needle or via an open technique using direct insertion of a trocar through a small incision. Each method has its potential advantages.

**Module 2 – Intraoperative Considerations 🡪 Pneumoperitoneum Establishment and Trocar Placement 🡪 Veress Needle Technique:**

1. The veress device is a spring-loaded needle. The cylindrical outer hollow needle has a sharp tip which ends slightly proximal to a more distal blunt tip within the hollow shaft of the outer needle. The blunt tipped inner portion is the conduit for insufflation gas. Proper assembly may be required for reusable devices.
2. The site of initial trocar placement to establish pneumoperitoneum is frequently the umbilicus, mainly because the abdominal wall is thinnest at that location and it is centrally located. Alternative sites are chosen when there are umbilical abnormalities such as scar or previous umbilical hernia repair or when the umbilical location will not offer the optimal location for the operative site.
3. Veress needle insertion begins with a small incision through the skin and subcutaneous tissue, which will allow the tip of a needle to pass through. The size of the incision is dictated by whether or not the veress needle insertion site will also be used for trocar insertion. The incision is normally made in the periumbilical skin folds, although the incision is sometimes made directly in the center of the umbilicus. Another common and relatively safe place for insertion is the left upper quadrant along the anterior axillary line as this area is usually away from the previous incisions or operative sites. It is important to note that patients with previous ventral hernia repair may have a prosthetic that extends beyond areas of previous incisions. Review of the previous operative report can help determine the extent of a prosthesis. The open technique should be used any time there is uncertainty about the existence of adhesions beneath the veress needle insertion site such as when there is a scar or hernia present.
4. If using the umbilical region for veress needle insertion, the abdominal wall is lifted up by the surgeon on one side and the assistant on the other, who grasps skin and muscle on each side of the umbilicus and elevate the umbilical ring. The objective of elevating the abdominal wall in this manner is to create a safe distance between the peritoneum and retroperitoneal vascular structures. The veress needle is held like a pencil, with the abdominal wall elevated in the area of the umbilicus, the needle is passed through the incision, perpendicular to the plane of the abdominal wall. Normally, the needle tip can be felt as it passes through the layers of the abdominal wall. Usually, once the spring-loaded blunt portion passes the peritoneum, there is an audible click. Once no further resistance is felt, even if an audible click is not heard, the assumption should be made that the needle tip has penetrated the peritoneal cavity. Additionally, the tip of the veress needle should be freely mobile.
5. Ascertaining whether or not the tip of the veress needle is safely in the intraperitoneal location can be done by analyzing a variety of conditions upon insertion displayed here. The most accurate way to detect intraperitoneal placement is by connecting the insufflator tubing and initiating gas at a low or medium flow rate. If the pressure is low and there is carbon dioxide flowing, the needle is most likely in the correct intraperitoneal position. If the pressure is high and there is no carbon dioxide flowing, the needle tip is probably within the abdominal wall or against the abdominal viscera. If the needle tip is against the viscera, the pressure should decrease when the abdominal wall is lifted. If there is doubt about the intraperitoneal position of the tip of the veress needle, immediate aspiration can ascertain whether or not the needle is in a blood vessel or the GI tract. If the needle is not in a blood vessel or the GI tract, saline can be gently flushed through the needle. Free flow of saline with little resistance indicates intraperitoneal positioning. If there is too much resistance, the needle tip is probably within the abdominal wall. Alternatively, in the hanging drop test, saline can be used to fill the needle such that a drop of saline appears just above the hub of the needle. The abdominal wall is then elevated on either side of the needle. If the drop of saline disappears through the needle, the tip is intraperitoneal. If not, the needle is in the abdominal wall. A final test is percussion of the abdomen after insufflation. Tympany with percussion indicates that a proper pneumoperitoneum has been achieved.
6. If not using an optical trocar, the first trocar must be inserted blindly into the peritoneal cavity when using the veress needle technique. Once the pneumoperitoneum has been raised to the desired intra-abdominal pressure, usually in the range of 10-15 mmHg, the veress needle is removed from the peritoneal cavity. It usually takes 1-3 L of CO2 to achieve this pressure. If the pressure is achieved only with a small amount of CO2, reconfirm the needle tip position and make sure the patient is adequately relaxed. If a small incision was initially made, the skin and subcutaneous tissue should be incised to enlarge the opening to allow passage of the trocar. Gastric decompression may help reduce the chance of injury to the stomach and should be considered prior to veress needle placement. Particularly if utilizing a site in the left upper quadrant.
7. Relative contraindications to blind insertion of the first trocar include the presence of previous abdominal surgery or a previous intra-abdominal inflammatory process that is likely to have caused adhesion of organs to that region of the anterior abdominal wall. Surgeons should therefore insert the trocar only in a non-involved area. It should be considered an absolute contraindication to blindly insert a veress needle or trocar in the immediate vicinity of scars from previous abdominal surgery. It should also be considered a contraindication to blindly insert a veress needle or trocar over an area of abdominal wall that has been covered with mesh from a previous ventral hernia repair. The area covered by mesh may not be readily apparent by scars and careful history taking and review of previous operative reports are necessary to make this determination. If there is any uncertainty with regards to the extent of mesh on the abdominal wall, it is safest to perform a technique under direct visualization.
8. After making an adequate size skin incision, the trocar is inserted. The surgeon grasps the trocar in the palm of the hand, placing the top portion against the thenar eminence and the shaft between the index and middle fingers. The trocar is then inserted through the abdominal wall, making sure the wrist is not angled and remains in line with the forearm and shaft of the trocar. This will allow maximum control of penetration force as the trocar goes through the abdominal wall and resistance is lost. During insertion, a twisting motion is used in conjunction with a pushing motion, using the minimal amount of pushing force necessary to advance the trocar. This technique should be used regardless of whether or not the trocar has a knife blade tip, a plastic tip, a protective spring-loaded shield or optical tip.
9. There are many types of trocar tips available, all of which have different mechanisms and designs. For this reason, the surgeon should be familiar with the mechanics of the device as well as manufacturer recommended insertion techniques prior to inserting the trocar in the clinical setting.
10. Once the first, or primary, trocar has been successfully inserted, the first step of the operation is to inspect the area immediately below the veress needle and trocar insertion site. The initial inspection scans the surfaces of the organs directly beneath the insertion site, looking carefully for any signs of inadvertent organ injury such as entero-contents, retroperitoneal hematoma, or significant intraperitoneal bleeding. Any evidence of inadvertent organ injury must be addressed appropriately and may warrant conversion to an open procedure. If an angled laparoscope is used, make sure the area directly under the insertion site is inspected adequately by adjusting the position of the laparoscope accordingly.
11. If a patient has undergone a previous abdominal operation, it is possible to safely insert a veress needle and trocar in an area away from the immediate vicinity of the scar. This does not mean that the insertion site can be close to the scar and the needle simply angled away from the scar. The insertion site must be a significant distance away from the scar as adhesions to the abdominal wall may extend beyond the immediate vicinity of the scar. A left upper quadrant veress needle insertion in patients with previous lower abdominal incisions is a typical example. Make sure to stay lateral to the epigastric vessels when using a site off the midline. Trocar insertion under direct vision using an open technique or optical trocar can be a safe alternative with proper training and experience.
12. Inadvertent organ injury may be seen with aspiration through the veress needle or initial laparoscopic inspection. There may, however, be complications not immediately related to the mechanical insertion of the trocar, rather the consequences of the pneumoperitoneum. Any cardiopulmonary compromise should prompt immediate evacuation of the pneumoperitoneum and reassessment of the cardiopulmonary status. It is important to note, however, that a retroperitoneal hematoma or intraperitoneal bleeding away from the field of vision may present with hypotension if unrecognized initially. A high index of suspicion should prompt immediate steps to identify a potential head and vascular injury. Although rare, pneumothorax and gas embolism may occur within initial insufflation and should prompt immediate treatment.

**Module 2 – Intraoperative Considerations 🡪 Pneumoperitoneum Establishment and Trocar Placement 🡪 Open Technique Using Hasson Trocar:**

1. The open technique for insertion of the primary trocar via small incision may be used for patients with or without previous abdominal surgery. A midline scar that involves the umbilicus has a much greater chance of intra-abdominal organ adhesions beneath the site. In such situations, the open technique must be performed with great caution. Alternatively, the surgeon may choose to make a small incision above or below the existing midline scar or at a remote site for primary trocar insertion using the open technique. Utilizing an open technique does not guarantee avoidance of an inadvertent organ injury but may make recognition of such injuries more obvious. Early recognition and treatment of inadvertent organ injury should improve patient outcomes.
2. The open technique is usually performed when using a blunt tip primary trocar. While this technique can be used anywhere in the abdomen, we will describe the technique as it relates to the commonly used periumbilical insertion site. An approximately 2 cm vertical or horizontal skin incision is created adjacent to the umbilicus. The precise location of the incision site is dictated by surgeon preference, previous scars, or other local anatomic considerations. The incision is carried down through the skin and subcutaneous tissues in order to clearly expose the fascia. Elevating the base of the umbilicus with a Kocher clamp can help expose the fascia by elevating into the wound. This is particular helpful in obese patients.
3. Once adequate exposure to the fascia is obtained, the fascia is incised with either a scalpel or the cutting current of a monopolar cautery handpiece. It is helpful to place anchoring sutures in the fascia while it is well exposed. A simple suture on each side of the opening or a horizontal mattress suture with a 0 or 2-0 long absorbable suture is preferable. These sutures may be placed before or after entering the peritoneal cavity and may also be used to close the fascia at the end of the procedure.
4. Once the fascia is incised, dissect carefully through the preperitoneal fat and identify the peritoneum. Lift up the peritoneum and grasp it with two clamps. Then, incise the peritoneum with a scissors or scalpel. If there is uncertainty about whether or not you have entered the peritoneal cavity, direct palpation with the index finger may be helpful. If the peritoneum has not been entered and direct palpation is performed, this may push the peritoneum further away from the incision and make entry more difficult. A combination of this tactile appreciation as well as direct visualization is often needed in obese patients.
5. Once an adequate size opening in the peritoneum is made, the blunt tipped trocar is inserted into the peritoneal cavity under direct visualization and secured to the fascia with the previously placed stay sutures. Once the port is secured, the insufflator tubing is connected, and the pneumoperitoneum initiated. Remember that even with the open technique, the first step after inserting the laparoscope should be to inspect the area directly under the port site, particularly if the insertion was technically difficult.
6. After successful placement of the primary trocar and establishment of the pneumoperitoneum, additional trocars are now placed. Once a clear area of the abdominal wall is identified, the precise location of trocar insertion may be ascertained by palpating the abdominal wall with the index finger while observing this palpation with a laparoscope. If there is a doubt about the exact location from the laparoscopic view due to the patient’s specific anatomy, a needle long enough to penetrate into the peritoneum is very helpful. This will then minimize the chance that the trocar will penetrate the peritoneum out of the field of view.
7. Additional trocars are now placed adhering to the following principles. Select a general location that will optimize the ergonomic working position of the surgeon and assistant. Select the exact location with finger palpation or a finder needle. Grasp the trocar such that the top is against the thenar eminence of the palm, the shaft is between the index and middle fingers, and the wrist is in line with the shaft. Insert the trocar into the peritoneal cavity under direct laparoscopic vision. Avoid placing trocars in the middle of the rectus muscles to avoid injury to the inferior epigastric vessels. These vessels cannot generally be seen with transillumination of the abdominal wall.

**Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum**:

This section will review the cardiovascular, renal, and other effects of carbon dioxide gas, the most commonly encountered gas used for insufflation and laparoscopic surgery.

**Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum 🡪 Overview of CO2 Pneumoperitoneum:**

1. Unlike thoracoscopy, the use of pneumoperitoneum is mandatory for laparoscopy. Even with so-called gasless abdominal lifting techniques, unpressurized air fills the working space to allow visualization of the operative field. Since the vast majority of laparoscopic procedures worldwide utilize carbon dioxide delivered by a device called an insufflator, the physiology discussion will refer to CO2 pneumoperitoneum obtained with this type of device. It is important to note that CO2 insufflation for laparoscopic surgery has both chemical and mechanical effects on physiology. Physiologic effects caused by CO2 pneumoperitoneum that merits specific attention include pulmonary, renal, and cardiovascular alterations.
2. Once pneumoperitoneum has been established, it is important to monitor the patient closely for physiologic abnormalities caused by both the pressure and chemical effects of the pneumoperitoneum. This is particularly important within the first 15-20 minutes, but monitoring should continue throughout the procedure.

**Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum 🡪 Carbon Dioxide – Chemical and Pressure Effects:**

1. CO2 is the preferred gas for establishment of pneumoperitoneum because it is rapidly absorbed, easily eliminated, and suppresses combustion. The diffusion coefficient of CO2 is almost 20x that of oxygen, which makes it very soluble in blood and easily carried to the alveoli for elimination. CO2 is readily available and readily inexpensive.
2. As the rate of absorption of CO2 across the peritoneal membrane overcomes the elimination by the lungs and buffer system, there is a relatively rapid rise in the patient’s arterial CO2 and end tidal CO2 concentrations, with an accompanying drop in the serum pH. The rate of change is greatest during the first 15-20 minutes, then slowly increases to a steady state after approximately 1 hour. These changes seem to be independent of the mechanical effects of the pneumoperitoneum. Although these changes are usually well tolerated, patients with severe cardiopulmonary disease are at a higher risk for adverse sequelae. These patients should be monitored with heightened vigilance, especially during the first 15-20 minutes of insufflation. End tidal CO2 monitoring should be considered essential in these patients.
3. CO2 is rapidly absorbed from the peritoneal cavity into the circulation and the primary mechanism for removal is through the lungs via increased minute ventilation. Additionally, increased intra-abdominal pressure pushes the diaphragm cephalad, causing reduced functional residual capacity, increased airway pressure, reduced pulmonary compliance, and reduced diaphragmatic excursion. These changes rapidly resolve once the pneumoperitoneum has been evacuated.
4. Although much of the chance in cardiovascular physiology with pneumoperitoneum is due to the pressure itself, the rise in CO2 concentration is also responsible for some changes. These chemical effects are specifically responsible for changes related to cerebral autoregulation of blood flow and vagal responsiveness to reverse Trendelenburg position. When considering pressure effects alone, lower initial flow rates and pressure seem to be associated with slightly less post-operative abdominal and shoulder pain when compared to higher flow rates and pressures.
5. Pressure effects of pneumoperitoneum can decrease venous flow and lead to venous thromboembolism or VTE. Each patient, however, should be assessed for their individual risk of VTE. Once the risk of VTE has been stratified for the particular patient, a tailored prophylactic regimen can be instituted. The suggested VTE prophylaxis, listed here, is based upon the SAGES guidelines published in October 2006. You may download a copy of these guidelines from the link on this page.

**Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum 🡪 Alternate Gases:**

1. There are alternatives to CO2 for establishment of pneumoperitoneum, although each has benefits and drawbacks.
2. The benefits of N2O as an insufflation gas compared to CO2 include less acid-base disturbance, increased ability for patients to tolerate pneumoperitoneum without anesthesia, and slightly less post-operative pain. Decreased acid-base disturbance may lead to fewer cardiopulmonary complications in patients with severe underlying cardiopulmonary disease. One drawback is that nitrous oxide does not suppress combustion hence is theoretically at increased risk to support an intraoperative fire. It is important to note that nitrous oxide is not flammable itself and will not ignite when used with monopolar or bipolar electrocautery. The only time a fire hazard does exist is when there is a combustible gas present, such as nitrogen or methane, present only when with a concomitant bowel injury when the GI tract has not been prepped with a mechanical lavage. Therefore, nitrous oxide should not be used as an insufflation gas when there is suspected bowel perforation or cases that are at higher risk for bowel perforation. Additionally, clinical trials have not shown bowel distention to occur as a result of nitrous oxide insufflation.
3. Inert gases such as argon and helium also eliminate the complications of hypercarbia and acidosis but are much less soluble in blood. This decreased solubility increases the risk of extraperitoneal gas extravasation such as gas embolus. Additionally, compared to carbon dioxide, these gases are much more expensive, and insufflators designed for their use are not readily available.

Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum 🡪 Cardiovascular Effects:

1. While there is variability in the physiological response to pneumoperitoneum, the pressure effects, and to some extent, the chemical effects are usually manifest with increased preload, increased afterload, and decreased cardiac output.
2. Cardiac output is regulated by a number of complex physiologic mechanisms that can be affected by CO2 pneumoperitoneum, which can cause hypercapnia. While these effects are variable among individuals, there is usually a decrease in cardiac output that is exacerbated by hypovolemia and reverse Trendelenburg position. If the drop is severe enough, which is unusual, it will manifest itself by signs and symptoms of reduced tissue perfusion such as hypotension, cardiac arrhythmia, decreased urine output, and increased end tidal CO2. One cause of severe low cardiac output is vagally induced bradycardia.
3. It is best to take measures to prevent significant drops in cardiac output during CO2 pneumoperitoneum. The surgeon should have a checklist of actions to undertake if clinically significant hypotension does occur intraoperatively. These actions are listed here.
4. Most patients undergoing laparoscopy have changes to their cardiac rhythm. The most common change is an increased heart rate or sinus tachycardia. This is usually mild and self-limited but could troublesome in patients prone to cardiac arrhythmias. Premature ventricular contractions may also occur but are rarely problematic. These cardiac rhythm changes are partially due to the chemical effects of CO2 pneumoperitoneum but other factors, such as anesthetic techniques and response, also contribute to these changes. One arrhythmia thought to be associated with the pressure effects of pneumoperitoneum is bradycardia. This is thought to be vagally mediated and usually occurs soon after the pneumoperitoneum has been established. If bradycardia is symptomatic or severe, the surgeon should quickly stop insufflation and allow the existing pneumoperitoneal gas to escape by disconnecting the insufflation tubing from the port. Once the vital signs return to normal, reestablishing pneumoperitoneum at a lower flow rate and pressure usually solves this problem. If the patient continues with severe arrhythmias due to pneumoperitoneum, consideration should be given for converting to the traditional open technique or aborting the procedure, depending on clinical circumstance.
5. The cardiovascular response to pneumoperitoneum is not limited to the heart and arterial system. The venous system is also at play due to the pressure effects of pneumoperitoneum on venous outflow from organs in venous return to the heart. Of specific concern is the potential risk for VTE. Venous flow rates drop anywhere from 26% to 39% during pneumoperitoneum, however, the incidence of VTE following laparoscopic cholecystectomy is less than 0.5%. While laparoscopy itself is not thought to increase the risk of VTE compared to open surgery, there are specific strategies to prevent this complication when performing laparoscopic surgery. The overall concept of this approach is to develop a strategy based on each individual patient’s risk. A guideline for risk stratification is shown here.

**Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum 🡪 Renal Effects:**

1. Urine production is an unreliable indicator of volume status during laparoscopic procedures. Increased intraabdominal pressure decreases renal blood flow which results in decreased filtration and urine output. A secondary release of renin and ADH results in sodium and free water reabsorption and oliguria. Post operatively, urine output often remains low for a short period of time until hormonal mediators restore hemostasis. A lack of understanding regarding the effects of pneumoperitoneum or urine output may prompt the physician to prescribe excessive intravenous fluid administration and result in fluid overload and congestive heart failure and/or pulmonary edema in patients with poor cardiac function.

**Module 2 – Intraoperative Considerations 🡪 Physiology of Pneumoperitoneum 🡪 Additional Considerations:**

1. In addition to the chemical and mechanical effects of pneumoperitoneum, the surgeon needs to be aware of issues related to hypothermia, extraperitoneal gas extravasation, and properly functioning equipment. Regarding hypothermia, the use of warmed and humidified CO2 is associated with statistically significant differences in body temperature and post-operative pain compared to standard CO2 directly from the cylinder, but these differences are not clinically significant, particularly with operations lasting less than approximately 90 minutes. It is also important to note that the CO2 cylinder be kept upright to avoid liquid at the bottom of the CO2 cylinder escaping into the insufflator. Extraperitoneal gas extravasation is intentional when performing extraperitoneal laparoscopy and may manifest during intraperitoneal laparoscopy in a variety of ways listed here. Additional equipment concerns are also important to consider.
2. Avoiding hypothermia during laparoscopy should have the same advantages as with traditional open procedures. Strategies are the same as for open operations and include using warmed IV fluids, a forced air body surface warmer and warm room temperatures. The use of warmed insufflation gas has not been proven to avoid clinically significant drops in body temperature in humans.
3. Clinically significant gas embolism during laparoscopic surgery is a rare event, occurring in less than 1% of cases. Studies with continuous transesophageal echocardiography during laparoscopic surgery suggest that clinically insignificant gas bubbles appear in the right heart chambers much more commonly. While rarely clinically significant, the manifestation of significant gas embolism is usually sudden cardiovascular collapse due to severely impaired venous return to the heart. This will be clinically apparent by the presence of severe hypotension, tachycardia, jugular venous distension, and possibly a characteristic mill wheel murmur. Treatment should consist of abrupt cessation of insufflation, evacuation of pneumoperitoneum, and positioning of the patient into the left lateral decubitus position with the head down to prevent the embolus from entering the right ventricular outflow tract. Rapid placement of a central venous catheter into the right atrium and ventricle may break up or allow aspiration of the gas embolus and restore normal cardiac blood flow.
4. The risk of disease transmission to the patient or operating room staff is an area of considerable concern, particularly with regard to bacterial contamination. Evacuated pneumoperitoneum gas has also demonstrated the presence of whole cells and bacteria. Simple steps to avoid aerosol contamination of the operating room environment include using a device designed to evacuate particles from energy sources and evacuating the pneumoperitoneum at the end of the procedure into a suction container. As with any surgery, universal precautions should be used throughout the procedure.

**Module 2 – Intraoperative Considerations 🡪 Exiting the Abdomen:**

During the process of exiting the abdomen, it is vital to ensure hemostasis and properly manage evacuation of pneumoperitoneum.

**Module 2 – Intraoperative Considerations 🡪 Exiting the Abdomen 🡪 Exiting the Abdomen:**

1. Upon completing the major portion of the operation, it is imperative that the operating surgeon perform a careful and compulsive last look throughout the abdomen. This must include visualizing areas away from the primary dissection to not only reveal obscure bleeding but also to ensure that no visceral injuries such as distal trocar injuries or cautery burns have occurred. It is also advisable to reduce the pneumoperitoneum pressure slightly to look for venous ooze.
2. The most common sources of unrecognized bleeding are trocar injury to abdominal wall vessels, injury to vessels or organs, such as the spleen or the liver, away from the operative field, and tamponade of venous bleeding by pneumoperitoneum.
3. Suction drains may be placed at the time of a laparoscopic procedure and are generally inserted through the abdominal wall at a trocar site. Drains are most easily placed by pulling them through a trocar site using a laparoscopic assisted technique with a grasper. If a 10 or 12 mm port is being used, the drain may be pushed through the port itself. Pneumoperitoneum may escape through the drain through the tubing and result in a loss of operative field. The decision to place a drain, the location of drain placement, and post-operative management of the drain are no different than in standard open techniques.
4. It is recommended to actively evacuate as much of the pneumoperitoneum as possible at the conclusion of the intraabdominal portion of the procedure to help reduce post-operative pain. This figure depicts the normal duration of CO2 gas within the abdomen as determined by plain radiographs following uneventful laparoscopy.

**Module 2 – Intraoperative Considerations 🡪 Exiting the Abdomen 🡪 Port Site Closure:**

1. It may be important to close the fascia in larger port sites to prevent port site herniation, particularly when not using dilating type trocars. Typically, port sites 5 mm or smaller do not require closure of the fascia except perhaps in the pediatric age group. However, hernias at 5 mm port sites have been reported. The true incidence of port site hernia is unknown but is likely very low, probably less than 5%. Risk factors for developing a port site hernia have not been well defined but likely factors influencing the development of a port site hernia are similar to those for incisional hernia after open surgery. Abdominal wall closure at the port sites can be accomplished using open techniques, laparoscopic assisted techniques, or entirely laparoscopic techniques.
2. Open techniques of fascial closure should utilize retractors and instruments that allow for adequate visualization of the fascia. In some cases, using needles with an exaggerated curve may be helpful. In obese patients, it is sometimes necessary to enlarge the skin incision for adequate exposure.
3. For laparoscopic guided fascial closure, the suture must be carried through the skin incision and exit intraabdominally, lateral to the trocar, to include abdominal wall fascia. The fascial closure device is then reinserted on the opposite side of the trocar and withdraws the suture. A Keith needle can also be used to close the fascia. A Keith needle is inserted on one side of the port site, reversed intracorporeally using the grasper, and driven back through the abdominal wall on the other side of the port site.
4. Purely laparoscopic techniques involve suturing the fascia closed from the posterior aspect of the abdominal wall. Exposure of the fascia is poor in this situation, making it difficult to ensure proper abdominal wall closure.
5. The skin is then typically closed with subcutaneous stitches and/or Steristrips.