32 Laparoscopy

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Case:

A 68-year-old female presents with a long-standing history of menorrhagia and is scheduled to undergo a laparoscopic total hysterectomy

Past Medical History:	
Cardiac:	Hypertension
Pulmonary:	Obstructive Sleep apnea (OSA)
	Chronic Obstructive Pulmonary
	Disease, Stage II
GI:	Gastroespohageal Reflux Disease
	(GERD)
Endocrine:	Diabetes Mellitus Type II (DMII)
Medications:	Atenolol 25 mg orally twice daily
	Hydrochlorothiazide 25 mg orally daily
	Lisinopril 40 mg orally daily
	Nexium 40 mg orally daily
	Spiriva 2 puffs twice daily
	Albuterol 2 puffs prn
Allergies:	NKDA
Social Hx:	Ex smoker: 30 pack-years; quit 5 years ago
Physical Exam:	
Vital Signs:	BP: 125/75 HR: 51
	SaO2: 97% on Room Air
	Weight: 305 lbs Height: 68 in. BMI: 46.4
Lungs:	Clear to auscultation bilaterally
METS:	4–5
Labs:	Chemistry: 140| 102|18/ 150 Why hyponatremic, and bicarb a touch low?
	4.2| 24 | 0.9\ These abnl labs may make people 'overthink'.
CBC:	8\7.9/250
	/28\
ECG:	NSR @ 58 bpm
PFTs:	FEV_1: 60%
	FEV_1/FVC: 0.6

(continued)

1. Define laparoscopy.
   Laparoscopy is defined as a minimally invasive procedure where a laparoscope is used to enter the peritoneum. Once the peritoneal cavity is entered, insufflating gas creates a pneumoperitoneum. Laparoscopy may be used to examine abdominal or pelvic (pelviscopy) organs, diagnose conditions, and/or perform surgery [1].
2. Name some surgical procedures currently performed laparoscopically.
   Laparoscopic procedures can be performed on all abdominal organs and includes gastrectomy, anti-reflux and bariatric procedures, cholecystectomy, hepatic and pancreatic resections, bowel and rectal surgery, adrenalectomy, and splenectomy [2]. Urological procedures performed laparoscopically include prostatectomy and nephrectomy. Laparoscopic gynecological surgeries include hysterectomy, ovarian, and tubal procedures [3].
3. What are the advantages of laparoscopic surgery? Which specific patient populations benefit most from laparoscopic procedures?
   Advantages of laparoscopic surgery are several-fold. Recovery time is shortened. This is mostly due to minimal bowel manipulation during laparoscopy, reducing the incidence of postoperative ileus. Because of the smaller incisions associated with laparoscopic

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L.S. Aglio and R.D. Urman (eds.), *Anesthesiology*,
DOI 10.1007/978-3-319-50141-3_32

procedures, resultant scars are more cosmetic and there is less postoperative pain [4]. Decreased intraoperative blood loss and less frequent surgical wound infections are also seen [5]. For particular patient populations, i.e., morbidly obese patients and patients with significant cardiopulmonary comorbidities, the benefits of a minimally invasive procedure are truly apparent with respect to less postoperative pulmonary complications.

4. What are the disadvantages of laparoscopic surgery?
In addition to the steep learning curve for surgeons learning laparoscopic techniques, other disadvantages of laparoscopic surgery include poor depth perception and loss of dexterity due to limited range of motion using laparoscopic instruments [6].
5. What are some absolute and relative contraindications to laparoscopic surgery?
Most contraindications to laparoscopic surgery are relative and these risks must be compared to the benefits of a less invasive procedure. Relative contraindications include patients with pre-existing increased intracranial pressure (and/or space occupying lesion), severe hypovolemia and known right-to-left intracardiac shunts, for example, a patent foramen ovale [7].
6. What are optimal surgical conditions for laparoscopic surgery?
Optimal surgical conditions include gastrointestinal decompression via a bowel prep and or naso/orogastric tube placement. This permits easier and safer formation of the pneumoperitoneum for surgical exposure decreasing the chance of injury to organs when the instruments are inserted. Neuromuscular blockade relaxes abdominal wall muscles facilitating formation of the pneumoperitoneum [1, 8].
7. What is the gas of choice used to create the pneumoperitoneum during laparoscopy and why?
The gas of choice used to create the pneumoperitoneum is carbon dioxide (CO_2). This is due to its easy accessibility, low cost, and fairly inert and non-combustible properties. Carbon dioxide (CO_2) is highly soluble and rapidly buffered in blood and eliminated by the lungs [9].
8. What are the disadvantages to using carbon dioxide (CO_2)?
A disadvantage to using CO_2 as an exogenous gas for insufflation is that it is irritating to the peritoneum. Use of carbon dioxide may also lead to hypercarbia and respiratory acidosis and also cause metabolic, hormonal, and immunological adverse effects [10]. Although the incidence is low due to the high solubility of CO_2 in blood, the formation of a gas (CO_2) embolism could be catastrophic.

Preoperative concerns:

1. What concerns do you have about this patient's history and physical with regards to laparoscopic surgery?
Her baseline pulmonary history (COPD) and obstructive sleep apnea (OSA) can predispose her to postoperative pulmonary complications. Morbid obesity may make the procedure more technically challenging for the surgeon to perform, and other obstacles, such as difficult airway, difficulty with ventilation in head-down position and positioning injuries may materialize. This patient is also anemic, which is likely due to her presenting symptom of menorrhagia, and may lead to a lower threshold for blood transfusion.
2. How does this patient's medical history predispose her to postoperative pulmonary complications? What are the GOLD criteria? How are they best used?
This patient has Stage II COPD. The GOLD criteria are used to classify patients with COPD based on the severity of their degree of obstruction (Table 1). The degree of obstruction is determined by pulmonary function tests, specifically FEV_1 and FEV_1/FVC [11]:

In order to better predict who may develop postoperative pulmonary complications, the GOLD criteria must be used in conjunction with other factors such as level of activity, smoking history, etc. The hypercarbia that develops during laparoscopy due to the use of CO_2 could be difficult to manage in patients with moderate to severe COPD resulting in hypercarbic respiratory failure postoperatively. Based on this patient's age, history of moderate COPD and OSA, and surgical site, she would be expected to have an increase in postoperative pulmonary complications, such as hypoxemia, atelectasis, hypercapnia, pneumonia, and ventilatory failure [12]:

- Age: The risk of postoperative pulmonary complications increases as a patient ages (>65) regardless of their baseline pulmonary status.
- COPD: See above table. Patients with mild COPD along with other significant comorbidities, and patients with moderate to severe COPD have a significant increased risk of postoperative pulmonary complications. Considering the patient's overall medical condition at the time of surgery, the relative risk of pulmonary complications is 2.7–4.7 [13].
- OSA: Though not currently routinely screened preoperatively in all patients, new data suggests an association between OSA and postoperative pulmonary complications [12].

- Surgical site: For incisions closer to the diaphragm, the risk of postoperative pulmonary complications increases.

Intraoperative concerns:

1. What are the three main causes of the physiological changes seen with laparoscopic surgery?
   Whether separate or in combination, the occurrence of the following are the main causes of the physiological changes seen during laparoscopic surgery:
   (a) Pneumoperitoneum: A pneumoperitoneum is essential for performing laparoscopic surgery. Creating, maintaining and dealing with the consequences of increased intra-abdominal pressure can lead to many problems intraoperatively [14].
   (b) Carbon dioxide: Although CO_2 for insufflation is the preferred gas based on its inert and non-combustible properties, absorption of this gas into the blood stream can cause pathophysiological effects on multiple organ systems.
   (c) Patient position: Trendelenburg and reverse Trendelenburg both have profound effects on a patient's hemodynamics.
2. What effect does laparoscopy have on the arterial to end-tidal CO_2 gradient (P_aCO_2-$P_{ET}CO_2$)?
   In ASA I & II patients, the reliability of $P_{ET}CO_2$ for monitoring P_aCO_2 is generally not affected by the use of CO_2 as an insufflation gas during laparoscopy. This may not be the case for ASA III & IV patients, however. For these patients, the increase in alveolar dead space and/or increased ventilation/perfusion mismatch that occurs with laparoscopic insufflation may increase the normal alveolar–arterial (A-a) gradient (normally 3–5 mmHg) where even with a normal $P_{ET}CO_2$, the P_aCO_2 may be significantly elevated [15].
3. Does this patient need an arterial line? Why or why not?
   Based on this patient's history of Stage II COPD and OSA and the fact that $P_{ET}CO_2$ may not accurately reflect P_aCO_2, an arterial line may be beneficial. This will allow direct monitoring of P_aCO_2 which will aid in the management of the hypercarbia which occurs with laparoscopy.
4. What are the typical causes of hypercarbia seen during laparoscopic surgery?
   The hypercarbia observed during laparoscopy could be a result of diffusion of CO_2 from the peritoneal cavity; hypoventilation; increase in the production of CO_2 (i.e., lactate and ketoacids); increased dead space (i.e., pulmonary embolism, severe COPD) [16].
5. What effect does CO_2 absorption have on the cardiovascular system?
   Hypercarbia has direct and indirect stimulating effects on the cardiovascular system. When CO_2 is absorbed across the peritoneum, it is normally excreted through the lungs. This is due to its high solubility and diffusibility. If the patient is hypoventilated or has significant pulmonary disease where managing ventilation may be challenging, hypercarbia may occur and could cause acidosis [17]. Mild hypercarbia can stimulate the sympathetic system resulting in tachycardia and increased myocardial contractility. Moderate to severe hypercarbia causes myocardial depression as well as direct vasodilatation due to the resultant acidosis [18]. Severe hypercarbia can also cause cardiac arrhythmias especially in the setting of hypoxia.
6. How does increased intra-abdominal pressure affect the cardiovascular system?
   Normal intra-abdominal pressure is 0–5 mmHg and with insufflation it increases to 10–15 mmHg. Pressures exceeding 15 mmHg can cause abdominal compartment syndrome and compromise organ function. Creation of the pneumoperitoneum causes an increase in systemic vascular resistance (SVR) (due to compression of the abdominal organs and blood vessels) and to a lesser extent, a decrease in cardiac output (CO), which results in an overall increase in mean arterial blood pressure (MAP). The degree of overall increase in MAP is proportional to the increase in intra-abdominal pressure. In addition to the mechanical compression of the pneumoperitoneum, the increase in MAP is also a result of the release of catecholamines, vasopressin and the activation of the renin–angiotensin system. With intra-abdominal pressures exceeding 20 mmHg, a decrease in heart rate, blood pressure, and cardiac output may occur due to decreased preload. The observed decreases in cardiac output are related to decreased venous return from compression of the inferior vena cava. In order to minimize these effects, insufflation should occur slowly and at the lowest pressure to achieve adequate surgical conditions (<15 mmHg). Vasodilatory agents, opioids, etc., may be used to treat increases in SVR, while preloading with intravenous fluids prior to insufflation may prevent the decreases in venous return and cardiac output [1].
7. What cardiac arrhythmias can be seen with peritoneal distention?
   Rapid insufflation with high flow rates can result in cardiac dysrhythmias including severe bradycardia, nodal rhythms as well as asystole. This is likely due to the rapid stretch of the peritoneal cavity with insufflation, which can result in significant vagal stimulation [19].

Table 1 The GOLD criteria are used to classify patients with COPD

GOLD COPD staging			
Stage I	Mild COPD	$FEV_1/FVC < 0.70$	$FEV_1 \geq 80\%$ normal
Stage II	Moderate COPD	$FEV_1/FVC < 0.70$	FEV_1 50–79% normal
Stage III	Severe COPD	$FEV_1/FVC < 0.70$	FEV_1 30–49% normal
Stage IV	Very severe COPD	$FEV_1/FVC < 0.70$	$FEV_1 < 30\%$ normal, or $< 50\%$ normal with chronic respiratory failure present

8. How does the Trendelenburg position affect the cardiovascular system?
Head-down tilt or Trendelenburg position results in increased venous return (preload) and cardiac output. This is easily tolerated in healthy patients, however, in patients with poor left ventricular function, an increase in central volume and pressure may be deleterious [20].
10. How does increased intra-abdominal pressure (pneumoperitoneum) affect the respiratory system?
The pneumoperitoneum is the primary factor that influences pulmonary function during laparoscopic surgery. These influences include elevation of the diaphragm, increase in intrathoracic pressure and therefore, a decrease in lung compliance, an increase in airway pressure, and a reduction in the functional residual capacity. Most healthy, ASA I and ASA II patients tolerate these pulmonary changes without issue. However, in ASA III and ASA IV patients, specifically patients with pre-existing pulmonary disease, these effects can have severe consequences [21].
11. What effect does CO_2 absorption have on the respiratory system?
Hypercarbia seen during laparoscopic surgery as a result of CO_2 absorption into the blood can stimulate the respiratory center. Carbon dioxide levels above 100–150 mmHg will result in respiratory depression [21]. During laparoscopic surgery, attention must be paid to effective ventilation strategies to ensure adequate elimination of carbon dioxide. Hypercarbia can produce bronchodilation and severe hypercarbia with resulting acidosis may cause pulmonary vasoconstriction [19].
12. How does the Trendelenburg position affect the respiratory system?
On its own, the Trendelenburg position does not induce any significant pulmonary changes. However, in the setting of a pneumoperitoneum, the Trendelenburg position can exaggSerate the effects of the pneumoperitoneum by reducing lung compliance, increasing the airway pressure and reducing the functional residual capacity [21].
13. How does the pneumoperitoneum affect the renal system?
The pneumoperitoneum affects the renal system through its mechanical compressive effects. This compressive effect accounts for about 50% of the decrease in glomerular filtration rate that is observed during laparoscopic surgery. Renal plasma flow and urine output are also decreased. These effects may remain despite adequate hydration; therefore, it is thought that the oliguria observed during laparoscopic surgery is due to neurohumoral alterations secondary to hypercarbia, as well as due to the compressive effects of the pneumoperitoneum [22]. With intra-abdominal pressures below 15 mmHg, the oliguria is reversible [23].
14. How does hypercarbia affect the central nervous system?
Hypercarbia during laparoscopic surgery can have direct effects on the central nervous system. Cerebral blood flow varies proportionately with $PaCO_2$. Cerebral blood flow increases 1–2 mL/100 g/min for each 1 mmHg increase in $PaCO_2$. Therefore, intracranial pressure may be increased with CO_2 insufflation and resultant hypercarbia. Mild hypercarbia directly causes cortical depression and increases the seizure threshold, however, increased levels of CO_2 directly stimulates the subcortical hypothalamic centers and may result in increased cortical excitability and seizure activity. At extreme levels of hypercarbia, general anesthesia is induced due to cortical and subcortical depression, which is most likely due to reduced intracellular pH causing intracellular perturbations [14, 24].
15. Should nitrous oxide be used during laparoscopic surgery? Why or why not?
There is controversy on whether or not nitrous oxide should be used during laparoscopic surgery. The two main issues are the potential of nitrous oxide to cause bowel distention and postoperative nausea and vomiting. The argument for increased bowel distention revolves around the fact that nitrous oxide is about 30 times more soluble than nitrogen, which means in a closed air-containing space (i.e., bowel), nitrous oxide will enter faster than nitrogen can be eliminated, thereby increasing the size of the closed air-containing space. However, studies have shown no significant effect on surgical conditions when nitrous oxide was used during laparoscopy. In addition, several studies found no increase in the incidence of postoperative nausea and vomiting when nitrous oxide was used during laparoscopic surgery [25, 26].

16. Is local or regional anesthesia a reasonable choice for laparoscopic surgery? Why or why not?
Although general anesthesia is the anesthetic technique of choice for laparoscopic surgery, local and regional anesthetic are optional and feasible techniques. Local anesthesia involves infiltration of local anesthetics into the surgical incisions (by surgeon) to minimize surgical incision pain, however, the abdominal cavity is not anesthetized, which may result in discomfort for the awake patient. Intravenous sedative and narcotics may be given for patient comfort. Regional neuraxial anesthesia entails injecting a local anesthetic near the spinal cord (spinal or epidural). The block would need to reach the T4 level for laparoscopic surgery [27]. The advantages of local or regional anesthesia for laparoscopic surgery are the avoidance of general anesthesia and its associated risks (e.g., airway trauma, sore throat, postoperative nausea, and vomiting) and need for less opioid use [28]. Disadvantages of local anesthesia include increased patient anxiety and pain (specifically shoulder pain as a result of CO_2 insufflation), which may require administration of sedatives and/or opioids, which may lead to respiratory depression [28]. Disadvantages of regional anesthesia used for laparoscopic surgery include requirement of a high level (T4) block, which could potentially lead to cardiac depression, bradycardia, hypotension due to the sympathectomy, and shoulder pain, among others [29].
17. What are the potential intraoperative complications that may occur during laparoscopy?
Several potential intraoperative complications may occur during laparoscopic surgery:
Complications with access into the peritoneal cavity. Access to the peritoneal cavity can be obtained by several methods. The closed method involves blindly passing the Veress needle into the abdominal cavity via a small incision at the umbilicus [30]. The pneumoperitoneum is established once the Veress needle is verified to be in the correct position. The open method involves the surgeon making an incision at the umbilicus through the skin, abdominal fascia and peritoneum under direct vision, followed by insertion of a Hassan trocar and establishment of the pneumoperitoneum [30]. Both methods of access could potentially cause complications. The rate of complication associated with the placement of the Veress needle or a trocar was approximately 0.3% [30]. These complications include injuries to major retroperitoneal blood vessels and/or bowel, solid organ injury, abdominal wall hematoma, wound infection, avulsion of adhesion, and fascial dehiscence and herniation [30, 31]. Although major vascular and bowel injuries with trocar insertion are rare, studies have shown that use of the open method may decrease the incidence of these more serious complications [30].
Complications related to the formation of the pneumoperitoneum. Complications related to the creation of the pneumoperitoneum by insufflating a gas include subcutaneous emphysema, mediastinal emphysema, and pneumothorax, which are due to the improper placement of the Veress needle or trocar [31]. Other complications related to the insufflation of CO_2 include cardiac dysrythymias, carbon dioxide retention and respiratory acidosis, postoperative pain related to retained intra-abdominal gas and venous CO_2 gas embolism [31]. The pneumoperitoneum may also lead to several hemodynamic changes, including stimulation of the neurohumoral vasoactive system with resultant release of catecholamines and increased heart rate, mean arterial pressure and systemic and pulmonary vascular resistance and decreases in venous return, preload and cardiac output [31]. In ASA I and ASA II patients these physiological changes are tolerated well when the intra-abdominal pressure is kept at or below 15 mmHg.
Other complications. Other complications include those that could occur as a result of the Trendelenburg position, such as venous congestion of the head and neck, increased intracranial and intraocular pressure, corneal and conjunctival edema, endobronchial intubation, and hypoxemia [14].
18. How may a pneumothorax manifest? How would you detect/diagnose a pneumothorax?
Pneumothorax is a known complication of laparoscopic abdominal surgeries. It is characterized by the abnormal collection of air or gas in the pleural space. During laparoscopic procedures, the CO_2 is under pressure in the abdomen and can track along anatomical paths, such as the esophageal hiatus, and enter the pleural space and cause separation between the lung and the chest wall [32]. Associated risk factors for the development of a pneumothorax during laparoscopic surgery include surgery times exceeding 200 min, positive end-tidal $CO_2 > 50$ mmHg, advanced patient age and operator inexperience [32, 33]. A pneumothorax can be detected intraoperatively by decreased total lung compliance, increased airway pressure and increased P_aCO_2 and $P_{ET}CO_2$. Significant hemodynamic changes, such as jugular venous distention, hypotension, absent breath sounds, bulging diaphragm, and expanding subcutaneous emphysema may be observed, especially with a tension pneumothorax [32]. Changes in the electrocardiographic (ECG) pattern may be a sensitive marker of a pneumothorax. Here, the amplitude of the QRS complex in the anterior precordial leads is reduced [34]. A pneumothorax may also be detected postoperatively with the patient exhibiting signs of restlessness and respiratory

distress. To confirm both an intraoperative and a postoperative pneumothorax, a chest radiograph should be obtained, unless there is suspicion of a tension pneumothorax, where needle decompression may be warranted before obtaining imaging. Also, ultrasonography has been shown to aid in the diagnosis of a pneumothorax and can also help determine the treatment [35].

19. How is a pneumothorax treated?
A laparoscopic gas-induced pneumothorax usually resolves spontaneously, as CO_2 quickly diffuses out of the chest. Administering 100% oxygen for both an intraoperative or postoperative pneumothorax, in addition to adding PEEP and increasing the minute ventilation intraoperatively is appropriate. Serial X-ray films and/or arterial blood gases should be obtained to monitor resolution of the pneumothorax. Insertion of a chest tube is usually unnecessary with a laparoscopic gas-induced pneumothorax [32, 35].
20. What could result from an endobronchial intubation?
Endobronchial intubation during laparoscopic surgery may present as hypoxemia and increased airway pressures [36]. Several factors during laparoscopic surgery may contribute to the high risk of endobronchial intubation. Though patient position (Trendelenburg) may be a factor, it appears that the pneumoperitoneum from abdominal insufflation is the main contributing factor to endotracheal tube migration during laparoscopic surgery [37].
21. What are the differences between air and CO_2 (gas) embolism?
A gas (or air) embolism occurs when a blood vessel is open and a pressure gradient exists that leads to gas entering the blood vessel. Gas embolism may occur as a result from injury of blood vessels during the blind insertion of the Veress needle with insufflation of CO_2 directly into the vessel during laparoscopic surgery [14]. Distinguishing a gas embolism from an air embolism is important since the latter may have catastrophic consequences. The main differences include composition of the embolism and its solubility in blood and the effect of using nitrous oxide in its presence [38]. The composition of an air embolism is 79% nitrogen and 21% oxygen, where the CO_2 (gas) embolism) is 100% CO_2 [14, 38]. This is an important distinction when it comes to the size of the embolism, where one could see cardiovascular collapse with an air embolism but not with an equally sized CO_2 embolism because of the high solubility of CO_2 in blood. Air embolism occurs when air is entrained into an open blood vessel, usually above the heart.
22. What are the possible signs of a significant CO_2 embolism? How may you diagnose a CO_2 embolism?
The clinical presentation of carbon dioxide embolism ranges from asymptomatic to cardiovascular collapse and death [39]. The presentation depends on the rate and volume of CO_2 entrapment and the patient's condition. Due to its high blood solubility, CO_2 embolism usually causes less detrimental effects than those produced by air. The bronchoconstriction or changes in pulmonary compliance that are caused by air embolism are not usually seen with CO_2 embolism [39]. At its worst, carbon dioxide embolism may present as a "gas lock" effect, which can cause right and left heart failure due to right ventricular obstruction, paradoxical embolism with or without a patent foramen ovale, dysrthythmia or asystole, pulmonary hypertension, systemic hypotension and cardiovascular collapse [39]. A "mill-wheel" murmur can be auscultated if the embolism is large enough. Without an increase in minute ventilation, the end-tidal CO_2 would decrease, though the arterial partial pressure of CO_2 would be increased [39]. The most sensitive method of diagnosing a CO_2 embolism is transesophageal echocardiography, with the transgastric inferior vena cava view being the ideal window for monitoring the appearance of carbon dioxide bubbles. However, transesophageal Doppler has recently been shown to be nearly as sensitive as transesophageal echocardiograpy and less expensive [39].
23. How would you treat a CO_2 embolism?
Immediate cessation of insufflation, release of the pneumoperitoneum, discontinuation of nitrous oxide, and increase in the FiO2 to 100 percent should occur if CO_2 embolism is suspected [40]. The patient should also be hyperventilated and placed in steep head-down and left lateral decubitus position (Durant's maneuver) to decrease the amount of gas that advances through the right side of the heart to cause obstruction of the right ventricular outflow tract [40]. In cases with profound hemodynamic compromise, a central venous or pulmonary artery catheter may be introduced for aspiration of the gas.

Postop:

1. What postoperative issues can be associated with laparoscopic surgery?

In addition to shoulder pain due to the retention of intra-abdominal gas, the effects of the pneumoperitoneum on respiratory function may continue into the postoperative period, requiring supplemental oxygen, non-invasive or high oxygen flow delivery systems [14]. Patients may also experience oliguria. The incidence of postoperative nausea and vomiting following laparoscopic surgery can be as high as 42% [41]. This is likely due to the rapid stretch of the peritoneum during abdominal insufflation, which may activate neurogenic pathways involved in inducing nausea and vomiting [42].

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