Subcutaneous Carbon Dioxide Emphysema Following Laparoscopic Salpingo-Oophorectomy: A Case Report

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Multiple patient and economic benefits have contributed to the widespread popularity of laparoscopic surgery. Although the laparoscopic approach is safe, it is not without potential complications. The following case study describes a patient undergoing a laparoscopic salpingo-oophorectomy who had a sudden rise in end-tidal carbon dioxide to 65 mm Hg and was found to have developed subcutaneous emphysema. Hyperventilation, close monitoring, and mechanical ventilation for 4 hours postoperatively resulted in a positive patient outcome. The mechanisms of carbon dioxide absorption, as well as risk factors, complications, treatment, and prevention of subcutaneous emphysema will be described.

Keywords: Carbon dioxide, hyperventilation, insufflation, laparoscopy, subcutaneous emphysema.

A laparoscopic approach for many intraperitoneal and extraperitoneal procedures was originally developed in the 1930s and has gained widespread popularity since the early 1990s. Laparoscopic surgery allows for smaller surgical incisions and minimal invasiveness, while still providing sufficient visualization of the peritoneal cavity. Carbon dioxide (CO₂) has proven to be a beneficial gas for insufflation because of its rapid diffusion ability, low cost, and decreased flammability compared with alternative gases. However, insufflation can cause CO₂ to diffuse into subcutaneous tissue, causing subcutaneous emphysema and hypercarbia. The resulting complications may include acidosis and increased sympathetic tone with hypertension and tachycardia resulting from the hypercarbia. The incidence of subcutaneous emphysema development during laparoscopic surgery is 0.3% to 3%. Risk factors for the development of subcutaneous emphysema during laparoscopy include increased age, extraperitoneal laparoscopic procedures, multiple surgical ports, high insufflation pressures, and prolonged surgical time. Recently, the influence of insufflation pressures and surgical duration has been demonstrated to have the most impact on the rate of CO₂ absorption. Because laparoscopy is a widely popular approach for many procedures, anesthetists must remain aware of the complications, risk factors, and measures to prevent unfavorable outcomes.

The following case study describes a situation in which a laparoscopic salpingo-oophorectomy resulted in unexpected complications due to inadvertent CO₂ absorption into the subcutaneous tissue.

Case Summary
An 80-year-old woman with a history of multiple ovarian cysts was scheduled for a laparoscopic bilateral salpingo-oophorectomy. The patient, classified as ASA physical status III, weighed 54 kg and had a history of atrial fibrillation, with a normal ejection fraction and no coronary artery disease. Her medications included warfarin, digoxin, metoprolol, omeprazole, and multivitamins. Surgical history included an appendectomy, hysterectomy, breast lumpectomy, and left knee arthroscopy. All of her surgeries were accomplished with general anesthesia and none of them were laparoscopic procedures. Her only past anesthetic complication was postoperative nausea.

An uneventful intravenous induction was performed using fentanyl, lidocaine, etomidate, and rocuronium. Placement of a 7.0-mm oral endotracheal tube was confirmed by positive end-tidal CO₂ and equal bilateral breath sounds. Anesthesia was maintained with desflurane combined with 50% oxygen and 50% air delivered by volume control ventilation. Minute ventilation was achieved with a delivered tidal volume of 600 mL and respiratory rate of 8/min. An oral gastric tube and esophageal stethoscope were inserted. The patient was given 10 mg of intravenous dexamethasone.

Initially following peritoneal insufflation, the patient was hemodynamically stable, with an end-tidal CO₂ reading of 33 mm Hg. However, 30 minutes after insufflation, the end-tidal CO₂ began to rise. The surgeon was notified and minute ventilation was immediately increased; however, the end-tidal CO₂ continued to steadily climb, peaking at 65 mm Hg. An arterial blood gas reading revealed a partial pressure of CO₂ in arterial blood gas reading (Paco₂) of 62 mm Hg. Minute ventilation was further increased to a tidal volume delivery of 750 mL and a respiratory rate of 24/min. While confirming bilateral breath sounds, subcutaneous emphysema...
was noted throughout the chest and neck. Surgery was discontinued prematurely after removal of only 1 ovary. The anesthesia team decided that the patient would need to remain intubated and mechanically ventilated until PaCO₂ levels returned to baseline. The patient remained in the postanesthesia care unit, ventilated and sedated, for approximately 4 hours until her CO₂ level returned to normal and the subcutaneous CO₂ emphysema subsided. Arterial blood gas results showed a pH of 7.37, PaO₂ of 200 mm Hg, and a PaCO₂ of 42 mm Hg. She was then extubated and admitted to the intensive care unit overnight. The patient was discharged home after 2 days with no complications.

Discussion

Since its introduction, laparoscopic surgery has gained widespread popularity that can be attributed to its many benefits when compared with traditional open surgical procedures. The small, minimally invasive incisions avoid muscle splinting, allow for faster healing, decrease bleeding, and reduce pain. Laparoscopy has been shown to be more expensive than similar procedures performed with an open technique due to the increased technical demands and longer duration of surgery. However, laparoscopic procedures have a positive overall economic benefit due to the shorter hospital stays necessary for patients, compared with those undergoing open procedures. Despite these benefits, laparoscopy also presents a unique set of possible complications.

Potential complications associated with laparoscopy include subcutaneous emphysema, pneumopericardium, pneumothorax, gas embolism, and visceral injuries. With the exception of visceral injuries, these problems occur because of the errant diffusion of CO₂. Intraperitoneal insufflation decreases pulmonary compliance, lung volumes, and venous return. These effects may result in ventilation-perfusion mismatching, increased airway pressure, and hypoxemia.

Kuntz, et al describe the use of CO₂, air, or helium for insufflation during laparoscopy. The effects on pH and intra-abdominal pressure vary with the use of different gases. According to this study conducted on rats, when using CO₂, blood pH decreased from 7.37 at an insufflating pressure of 0 mm Hg to a pH of 7.17 at a pressure of 9 mm Hg. The subcutaneous pH decreased to a critical low of 6.81 at a pressure of 9 mm Hg. The intra-abdominal pH decreased to 6.18 when CO₂ was used for pneumoperitoneum. However, when helium was used for insufflation, the subcutaneous pH decreased to no lower than 7.29 at an intra-abdominal pressure of 9 mm Hg. Similarly, with the use of air, the study found the subcutaneous pH decreased to only 7.24. The marked decrease in pH when using CO₂ compared with other gases is significant since it is the primary gas used for laparoscopy. The use of helium or air has fewer negative effects because they are not as readily absorbed by the tissue as CO₂ and are able to be completely eliminated via the lungs with little residual blood absorption. An average intra-abdominal pressure of 12 mm Hg is generally associated with a lower risk of complications. When compared to other studies, Kuntz et al found the influence of the selected gas and the intra-abdominal pressure to be more significant in causing pneumothorax, pneumopericardium, and mechanical displacement of the endotracheal tube than the duration of the pneumoperitoneum.

The port sites used in laparoscopic surgery vary in number depending on the type of surgery and the choice of gas used for insufflation. Often, CO₂ is used for insufflation because of its economic efficiency and decreased flammability in relation to alternate gases. Carbon dioxide insufflation creates a pneumoperitoneum, which helps to provide surgical visualization; however, the introduction of CO₂ into the abdomen presents numerous adverse effects. As CO₂ is introduced into the abdomen, it is absorbed into the peritoneum and subcutaneous tissue. About 200 mL/min of CO₂ is produced by the body while at rest. Normally, CO₂ travels through the capillaries to the venous system, where it is then carried via the pulmonary arteries to the lungs to be eliminated through exhalation. During laparoscopic surgery, subcutaneous tissue pH can decrease from 7.35 to 6.81, and blood pH can decrease to 7.17. These changes are up to 10% greater with the use of CO₂ than with other gases and can lead to hypercarbia, pulmonary hypertension, and acidosis. Hypercarbia increases cardiac output and arterial blood pressure, and can lead to respiratory acidosis and increased intracranial pressure.

According to a study that compared various insufflation gases at typical insufflation pressures, a 70-kg patient absorbs approximately 200 mL/kg per hour of CO₂ via the peritoneum, which equals 14 L/hour. The increase in intra-abdominal pressure during CO₂ insufflation and laparoscopy further contributes to acidosis because it may lead to decreased tissue and subcutaneous blood flow in the abdominal wall. By limiting diaphragmatic excursion, increased intra-abdominal pressure during insufflation contributes to decreased blood gas exchange. This decreases the removal of acidic products, such as hydrogen, CO₂, and ketones, which decreases the pH of the subcutaneous tissue. Ultimately, the increased abdominal wall tension decreases blood flow to the adipose tissue, which is normally poorly perfused compared with other tissues, preventing the body from correcting the tissue acidosis.

In the majority of laparoscopic cases, the incidence of acidosis or subcutaneous emphysema resulting from CO₂ absorption is uncommon. In some cases, inadvertent CO₂ insufflation into the subcutaneous tissue can lead to emphysema. As much as 12.0 L of CO₂ can accumulate in the
body during pneumoperitoneum. This may occur as a result of insufflation pressures greater than 12, or because of leakage of CO2 through the trocar sites as they pass though the skin and muscle. If the inner seal around the trocar site is not tight and the skin seal is, CO2 can escape into the subcutaneous tissue. This can also result from skin incisions that are too small for complete advancement of the trocar or from tearing of the seal due to manipulation of the instruments. When this occurs, muscles may also tear and further accentuate the subcutaneous emphysema. If a leak is present and CO2 escapes into the subcutaneous tissue, the amount of subcutaneous emphysema is directly proportional to the CO2 insufflation pressure, the duration of the procedure, and the ability of this tissue to resist absorption of the gas. During the procedure, minute ventilation may be increased as needed to overcome the acidosis from absorption of the CO2 and the decreased blood/gas exchange. Typically, this will sustain the patient at a normal pH throughout the procedure; however, in the presented case study, the CO2 absorption was great enough to be resistant to this intervention. Mild subcutaneous emphysema usually resolves quickly and does not result in negative patent outcomes. In rare cases, pneumothorax, pneumopericardium, severe acidosis, upper airway obstruction, and difficulty ventilating have occurred.

Although significant subcutaneous emphysema can occur in patients for no apparent reason, some risk factors have been identified. Singh et al demonstrated subcutaneous emphysema to be more common during extraperitoneal vs intraperitoneal laparoscopic procedures due to the larger CO2 absorption surface area provided by the expanded extraperitoneal space. Intraperitoneal procedures provide less surface area, and absorption is less common. Elderly patients have an increased risk for this complication because natural resistance to gas insufflation by the subcutaneous tissue likely decreases with age. Conversely, children have a minimal risk of CO2 emphysema. Other procedure-related risk factors include using more than 6 surgical ports, high insufflation pressures, and prolonged surgical time.

Vigilance and extreme caution should be taken to promptly recognize and treat subcutaneous emphysema. If subcutaneous CO2 absorption is present, it usually can be resolved easily so that no long-term complications result. High end-tidal CO2 is typically the first recognized sign of CO2 absorption. If this occurs, palpation of crepitus in the anterior chest extending upward into the neck may be noted, depending on the extent of CO2 absorption. Crepitus is the result of the diffusion of CO2 through the subcutaneous tissue in the neck. If crepitus is found, the surgical team must be promptly notified so surgical measures can be instituted to reduce complications. This may include creating a larger skin incision to allow escape of the CO2 and decreasing the insufflation pressure. In a typical 70-kg patient, minute ventilation should to be increased by 75% to achieve eucapnia in the subcutaneous tissue during laparoscopic procedures. However, this is usually difficult to achieve, and pH, particularly in the subcutaneous tissue, may still drop. Furthermore, such a large increase in minute ventilation can decrease cardiac output. Increasing minute ventilation by 30% is usually sufficient to increase blood pH to a normal level. In addition to hypercarbia, the prolonged Trendelenburg position required during some procedures and the decreased alveolar compliance caused by the pneumoperitoneum may contribute to atelectasis and hypoxemia. Recruitment of alveoli may be accomplished via several manual breaths held at a pressure of 30 mm Hg for 5 seconds each. This also promotes CO2 elimination while PaCO2 levels improve. If blood pH does not return to normal, surgery may need to be prematurely discontinued, as in the presented case study.

Radiographic studies including CT scan can determine the extent of subcutaneous emphysema if unclear by physical assessment and can rule out pneumothorax. Conservative, close management of the patient’s condition should be maintained. If subcutaneous CO2 is present following completion of the procedure, short-term postoperative ventilation may be required until the CO2 diffuses out of the subcutaneous tissue and there is no potential for airway compromise. Potential airway compromise may include upper airway obstruction, facial or neck swelling, and hypventilation. Acidosis that can result from excessive CO2 in the blood and subcutaneous tissue can lead to arrhythmias, increased intracranial pressure, and a depressed central nervous system if not corrected. The anesthetized patient relies on the anesthesia provider to manually implement the body’s first compensatory mechanism by increasing minute ventilation as previously described. Adequate hydration and sodium bicarbonate administration may be necessary for excessive acidosis, but they are not usually indicated for the respiratory acidosis caused by CO2 absorption. Administration of sodium bicarbonate may actually worsen the PaCO2, since one of the end products of sodium bicarbonate dissociation is CO2. Ultimately, because of the rapid diffusion properties of CO2, subcutaneous CO2 emphysema usually resolves in 1 to 4 days. Although not a favorable phenomenon, the occurrence of subcutaneous emphysema is not thought to cause any serious, long-term complications if blood pH is maintained close to normal.

Conclusion

The use of laparoscopy for a variety of surgical procedures has become increasingly popular due to numerous benefits it offers over open procedures. Smaller skin incisions and faster recovery times compared to open surgi-
cal procedures make the laparoscopic approach safe and beneficial to patients. However, the risk of subcutaneous CO₂ absorption, acidosis, pneumopericardium, and pneumothorax is present. Although CO₂ is relatively safe and cost effective, the choice of CO₂ over other gases for insufflation can lead to a more rapid gas absorption into the subcutaneous tissue. Other surgical factors, such as insufflation pressure and duration, strongly influence the magnitude of CO₂ absorption. Risk factors and preventative measures have been identified. Anesthesia providers need to understand the occurrence, risk factors, symptoms, and treatment to avoid negative or potentially life-threatening complications. In the case study presented, prompt recognition, hyperventilation, and surgical cessation resulted in a positive patient outcome.

REFERENCES

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