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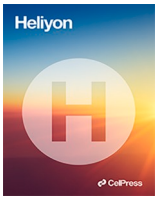

Case report

Massive subcutaneous emphysema and bilateral tension pneumothorax following laparoscopic inguinal hernia repair under general anesthesia: A case report

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ABSTRACT

The escalating adoption of laparoscopic surgical techniques has demonstrated their capacity to yield improved clinical outcomes. However, concomitant with the advantages of this minimally invasive approach, certain adverse complications have been reported. In this report, we present a noteworthy case involving a 72-year-old male patient who underwent laparoscopic inguinal hernia repair. The surgical procedure proceeded without noteworthy complications, and the patient maintained hemodynamic stability throughout. However, the post-anesthetic recovery was compromised by the onset of subcutaneous emphysema and bilateral tension pneumothorax. Immediate intervention was imperative, prompting the performance of an emergent needle thoracostomy, subsequently followed by the implementation of a closed drainage system within the thoracic cavity. These interventions proved efficacious in mitigating the patient's distressing symptoms. Although pneumothorax complications in the context of laparoscopic surgery are infrequent, it is imperative for anesthetists to remain vigilant regarding the potential occurrence of subcutaneous emphysema and pneumothorax in the perioperative period. This case underscores the significance of meticulous perioperative monitoring and rapid intervention, particularly in laparoscopic procedures, where the insufflation of carbon dioxide into the abdominal cavity can predispose patients to these rare yet potentially life-threatening complications. Heightened awareness among healthcare providers regarding the possibility of such events is pivotal in ensuring the safety and well-being of surgical patients.

1. Introduction

Nowadays, laparoscopic surgical techniques have become widely adopted as a minimally invasive approach for the treatment of

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inguinal hernia. Compared to conventional open surgery, it offers numerous benefits, including reduced blood loss and faster recovery for patients [1,2]. However, despite its advantages, this surgical method can also lead to complications, such as abdominal visceral injuries, vascular injuries, air embolism, cardiac arrhythmia, and abdominal wall injuries, among others [3–6]. Among these, pneumothorax is a relatively rare but severe and potentially fatal complication that the anesthesiologists might encounter. Given the potentially fatal nature, it is critical for surgeons and anesthesiologists to be vigilant about close monitoring, prompt recognition and emergency management. In this report, we illustrate a case of subcutaneous emphysema and bilateral pneumothorax following laparoscopic inguinal hernia repair in a patient without any pre-existing pulmonary conditions.

2. Case presentation

A 72-year-old male (weight: 65 kg, height: 172 cm) was scheduled for elective laparoscopic right transabdominal preperitoneal (TAPP) inguinal hernia repair. The patient had an unremarkable medical history with no history of lung pathology. His preoperative chest radiograph (X-ray taken) the day before the surgery revealed possible inflammation in the lower lobe of the right lung (Fig. 1A). Laboratory examinations showed a mildly reduced platelet count (50×10^9/L).

Upon arrival in the operating room, standard intravenous access was established, and vital signs were monitored. The anesthesiologist initiated general anesthesia by administering midazolam 2 mg, sufentanil 15 μg, propofol 150 mg, and succinylcholine 100 mg intravenously in succession. Following successful mask ventilation, a No. 7.5 endotracheal tube was selected and smoothly inserted for intubation. Mechanical ventilation was set with a tidal volume (VT) of 450 mL, respiratory rate of 14 breaths per minute, inspiratory/expiratory ratio of 1:2 and positive end-expiratory pressure (PEEP) of 5 cm H_2O. Anesthesia was maintained with 1 % sevoflurane, 1 L/min nitrous oxide (N_2O), and propofol at 4 mg/kg/h. During the operation, a trocar was inserted through a 1 cm incision at the upper edge of the umbilicus, and the abdominal cavity was insufflated with CO_2 at a pressure of 13 mmHg to establish pneumoperitoneum. Operating forceps were introduced through incisions at the lateral edges of the rectus abdominis muscles at the umbilical level. The preperitoneal space was accessed and dissected along a transverse incision approximately 6 cm in length above the internal hernia opening. The hernia sac was carefully dissected from the surface of the spermatic cord and retracted into the abdominal cavity. Dissection continued medially along the spermatic cord to expose the direct hernial triangle and the medial pubic pectineal ligament. Once the preperitoneal space was adequately prepared, a universal 3D inguinal hernia repair patch was introduced into this space. The peritoneal incision was then sutured continuously with absorbable sutures. Throughout the procedure, the patient's hemodynamics remained stable, and SpO_2 was maintained at 99–100 %. Adjustments were made to maintain end-tidal carbon dioxide partial pressure ($PetCO_2$) below 40 mmHg and peak inspiratory airway pressure between 19 and 24 cm H_2O.

The entire surgical procedure lasted approximately 1 h. Postoperatively, a minor amount of gas accumulation was observed in the patient's scrotal area. After the patient regained spontaneous respiration, he was transported to the Post-Anesthesia Care Unit (PACU) for further monitoring and removal of the endotracheal tube. Approximately 5 minutes later, the patient developed massive subcutaneous emphysema around the neck and face areas with high bilateral chest wall tension, indicating a possible pneumothorax. Due to

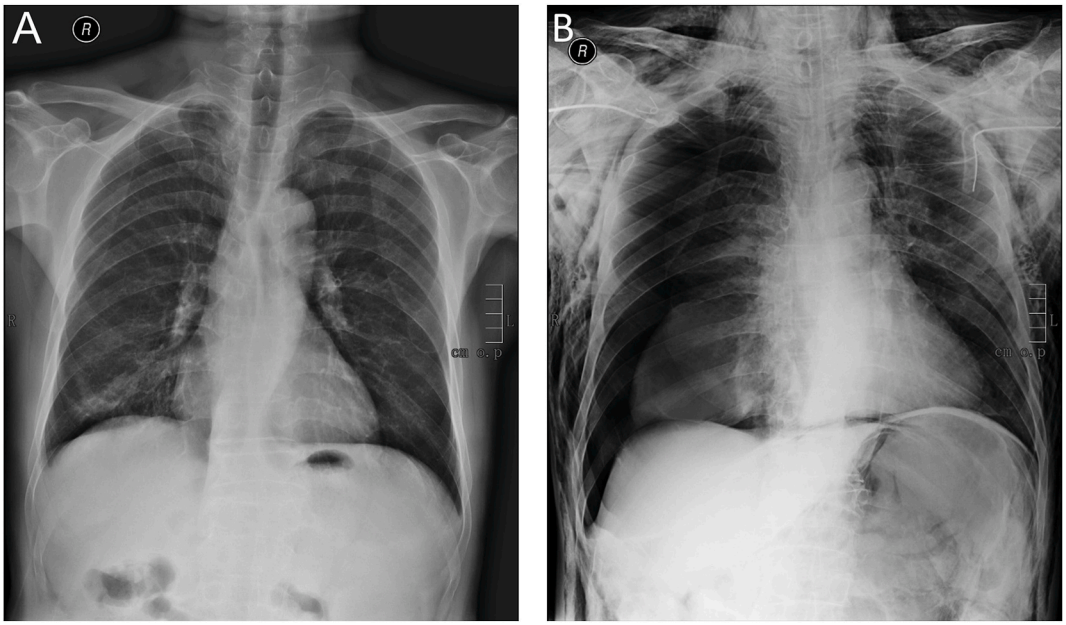

Fig. 1. Perioperative chest anteroposterior radiograph of the patient. Prior to the surgery, the patient's chest radiograph **A** indicated no evident abnormalities. On the day of the surgery, the postoperative chest radiograph **B** revealed bilateral pneumothorax accompanied by extensive subcutaneous emphysema in the chest and neck regions.

the rapid increase in intrathoracic pressure, the patient exhibited retrograde flow even in the peripheral venous infusion. Upon observing these abnormalities, the PACU personnel promptly reported to the senior anesthesiologist. Following the diagnosis of bilateral tension pneumothorax, the anesthesiologist immediately performed chest wall needle decompression and informed the thoracic surgeons to initiate emergency closed drainage of thoracic cavity. Concurrently, bilateral pneumothorax was confirmed via bedside X-ray assessment (Fig. 1B). After an uneventful and successful surgical procedure, the patient was transferred to the Intensive Care Unit (ICU) for continued management. On postoperative day 7, the patient was discharged from the hospital with an unremarkable recovery, free of any further complications.

3. Discussion

The exact cause of subcutaneous emphysema and pneumothorax following laparoscopic inguinal hernia repair is often uncertain, but several previous cases have proposed that gas may extravasate from the abdominal cavity into the thoracic cavity [7,8]. Laparoscopic hernia surgery typically includes the totally extraperitoneal (TEP) and TAPP procedures. Upon reviewing case reports related to complications such as subcutaneous emphysema and pneumothorax in laparoscopic hernia surgery (Table 1), we found that a greater number of complications were associated with the TEP procedure (16 out of 21 cases). This may be attributable to the narrow preperitoneal space and the tendency for CO_2 insufflation in this space, causing dissection along the subcutaneous fascial plane. Studies have demonstrated that the diffusion of extraperitoneal CO_2 into the body is greater than that of intraperitoneal CO_2 [5,9,10]. However, some studies have indicated that there is no significant difference in the incidence of complications between the TAPP and TEP procedures [11–13]. In our case, the surgical method used was TAPP.

Furthermore, upon reviewing our case reports collection, we found that the majority of complications occurred in male patients (19 out of 21 cases), likely due to a higher incidence of inguinal hernia in men. The larger inguinal canal in men predisposes them to the formation of inguinal hernias. Additionally, male hormones may influence the structure and function of abdominal wall muscles and connective tissues, thereby making inguinal hernias more prevalent in men [14,15]. In a separate study on the incidence of spontaneous pneumothorax by gender, it was found that the incidence in men was significantly higher than in women [16]. This discrepancy may be attributed to the fact that men, on average, are taller than women. The expansion stress at the apex of the lung is greater than in other parts, and taller individuals are more likely to experience bulla rupture due to gravitational effects [17,18]. Moreover, men are more prone to underlying lung diseases, often due to smoking and other habits, which further increases the risk of pneumothorax. Therefore, men may be more susceptible to these complications.

Additionally, 42.8 % (9 out of 21 cases) of these cases involved patients older than 45 years old, suggesting that pneumothorax and subcutaneous emphysema may be related to age-related factors. Although studies have not identified age as a direct risk factor for pneumothorax or subcutaneous emphysema during laparoscopic inguinal hernia repair surgery, the incidence of chronic obstructive pulmonary disease (COPD) and other pulmonary diseases increases with age. These conditions can lead to an imbalance in the pressure inside and outside the alveoli, potentially causing pneumothorax [19,20]. Additionally, during laparoscopic surgery, elderly patients, due to their multiple underlying diseases, prolonged operation times, loose subcutaneous tissue, and fragile connective tissue, are more susceptible to gas accumulation during pneumoperitoneum. This can result in complications such as subcutaneous emphysema and pneumothorax.

The insufflated gas from a pneumoperitoneum can enter the thoracic cavity through different routes, including diaphragmatic hiatuses (aortic, esophageal), congenital defects of the diaphragm, the Bochdalek foramen, or the retroperitoneal space [8,21]. In this case, there were neither signs of accidental diaphragmatic injury nor evidence of congenital defects. Notably, the only abnormality during the perioperative period preceding the subcutaneous emphysema and bilateral pneumothorax was the pneumatosis in the scrotum, which may be due to a failure to evacuate the gas in the hernia capsule. Additionally, the internal spermatic fascia is the continuation of the fascia transversalis, and further continuous with the endothoracic fascia. This allows the free gas to track along fascial planes and into the pleural space and subcutaneous tissue through the anterior gaps of the diaphragm [7,22]. In some cases, accidental damage to blood vessels during surgery may also cause intra-abdominal gas to enter the blood vessels, leading to rare but fatal complications such as gas embolism or pneumothorax [23,24].

In addition to the factors mentioned above, anesthetics are suspected to expand pneumothorax and subcutaneous emphysema. Although no definitive studies have established a direct link between N_2O and these complications, it is considered a potential risk factor for pneumothorax or subcutaneous emphysema in some studies [21,25]. The relatively low solubility in the blood of N_2O makes it a known rapid-onset and clearance inhaled anesthetic [26]. However, the inhalation of N_2O will rapidly diffuse into air-filled cavities, leading to rapid gas expansion and increased pressure in the closed space. As shown in an animal model, inhalation of N_2O for up to 30 minutes can increase the volume of a pneumothorax [27]. In this case, it is likely that the rapid diffusion of N_2O into the pleural space bilaterally, led to further expansion of free air in this space. As a result, the free gas was noted to extend into the tissues of the patient's neck in the PACU. Therefore, the inhalation of N_2O in our case might have been a critical factor contributing to the development of pneumothorax progression and extensive subcutaneous emphysema.

In our case, the patient's complications could be interpreted by one or more factors occurring simultaneously. Prior literatures have identified several other risk factors associated with pneumothorax, including $PetCO_2$ exceeding 50 mmHg, operative durations exceeding 200 minutes, and the utilization of six or more operative ports [28]. In this particular case, the surgical intervention successfully maintained the patient's $PetCO_2$ consistently below 40 mmHg throughout the entire procedure, while also ensuring a relatively brief operative duration of 60 minutes. Both of these metrics stayed within acceptable limits. Furthermore, our patient exhibited no known underlying pulmonary disorders or other predisposing factors.

In this particular case, the presence of pneumothorax in the patient was diagnosed based on the extensive subcutaneous

Table 1
Summary of pneumothorax and subcutaneous emphysema cases in laparoscopic hernia repair.

Reference	Age/Sex	Surgery	Technique	N_2O	Complication	Time of discovery	Treatment	Possible Causes
Omeroglu et al. [33]	31 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Bilateral pneumothorax and pneumomediastinum	During extubation	Spontaneous resolution	Increased carbon dioxide pressure, peritoneal breaches
Wallace et al. [34]	29 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Bilateral subcutaneous emphysema, pneumomediastinum and pneumothorax	Following extubation	Chest tube drainage	Extraperitoneal gas migration
Kim et al. [35]	56 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Right pneumothorax with subcutaneous emphysema	During surgery (about 50 minutes after CO_2 insufflation)	Chest tube drainage	Extraperitoneal CO_2 migration
Hagopian et al. [10]	Not mentioned	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Unilateral pneumothorax with pneumomediastinum and subcutaneous emphysema	After surgery	Spontaneous resolution	Gas extravastion due to airway or esophageal injury or pulmonary barotrauma.
Ramia et al. [9]	52 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Subcutaneous emphysema and pneumomediastinum	Immediately after extubation	Prolonged mechanical ventilation	CO_2 enters the mediastinum through small tears in the peritoneum.
Ishikawa et al. [36]	65 M	Robotic-assisted inguinal hernia repair	TAPP	Not mentioned	Bilateral pneumothorax	After surgery	Spontaneous resolution	Air migration, previous esophageal cancer surgery
Ghaffar et al. [37]	2 M	Laparoscopic inguinal hernia repair and orchidopexy	TAPP	Not mentioned	Right pneumothorax	After surgery	Chest tube drainage	Endobronchial intubation (leading to one lung ventilation), Escobar syndrome (ES)
Sucandy et al. [38]	48 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Right pneumothorax	In the postanesthesia care unit	Spontaneous resolution	Gas can enter the thoracic cavity through diaphragmatic hiatuses, congenital defects, falciform ligament damage, or retroperitoneal passage via Scarpa's fascia.
Bartelmaos et al. [39]	53 M	Laparoscopic inguinal hernia repair	TEP	Yes	Pneumomediastinum and right pneumothorax	In the recovery room	Spontaneous resolution	Peritoneal breaches, CO_2 diffusion
Ferzli et al. [40]	38 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Bilateral pneumothorax and pneumomediastinum	At completion of surgery	Spontaneous resolution	High insufflation pressures, long surgery duration
	40 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Massive subcutaneous emphysema, pneumomediastinum and right pneumothorax	During surgery	Spontaneous resolution	
Aldakhil et al. [41]	28 M	Laparoscopic inguinal hernia repair	Not mentioned	Not mentioned	Subcutaneous emphysema and hypercarbia	During surgery	Spontaneous resolution	CO_2 insufflation
Schmidt et al. [42]	71 M	Laparoscopic inguinal hernia repair	TAPP	Not mentioned	Subcutaneous emphysema	At the first postoperative day	Spontaneous resolution	CO_2 insufflation, spray application of fibrin glue
Benjamin et al. [43]	9-month F	Laparoscopic inguinal hernia repair	Not mentioned	Not mentioned	Subcutaneous emphysema	During recovery from anesthesia	Spontaneous resolution	Incompletely evacuated pneumoperitoneum and air escape.

(*continued on next page*)

Table 1 (*continued*)

Reference	Age/Sex	Surgery	Technique	N_2O	Complication	Time of discovery	Treatment	Possible Causes
Singh et al. [44]	53 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Subcutaneous emphysema and hypercarbia	During surgery	Spontaneous resolution	Excessive subcutaneous tissue thickness prevented the trocar cone from reaching the anterior rectus sheath, resulting in CO_2 leakage at the inner seal.
Klopfenstein et al. [45]	59 M	Laparoscopic inguinal hernia repair	TEP	Yes	Subcutaneous emphysema and hypercarbia	During surgery	Spontaneous resolution	CO_2 insufflation
Cheng et al. [46]	23 M	Laparoscopic inguinal hernia repair	TEP	No	bilateral pneumothoraces and subcutaneous emphysema	During surgery	Chest tube drainage	Insufflation of CO_2 in the preperitoneal space can lead to dissection along subcutaneous fascial planes, retroperitoneal tracking, and the formation of pneumoperitoneum. Young, thin men are particularly at risk of developing a pneumothorax.
Nikolaos et al. [47]	73 M	Laparoscopic inguinal hernia repair	TEP	No	Bilateral subcutaneous emphysema and pneumothorax	After surgery	Conservative	Gas can enter the thoracic cavity through diaphragmatic hiatuses (aortic, esophageal), the retroperitoneal space, the Bochdalek foramen, and congenital diaphragmatic deformities.
Christopher et al. [48]	44 M	Laparoscopic inguinal hernia repair	TEP	No	Right pneumothorax	During surgery	Chest tube drainage	High CO_2 insufflation pressure.
John et al. [49]	25 M	Laparoscopic inguinal hernia repair	TEP	Yes	Left pneumothorax	After surgery	Chest tube drainage	Gas entry into the thoracic cavity can occur via congenital defects, tracheal injury, bulla rupture, or central venous line complications. The utilization of N_2O.
Madan et al. [25]	64 M	Laparoscopic inguinal hernia repair	TEP	Not mentioned	Pneumomediastinum.	After surgery	Conservative	Inadvertent tear in the peritoneum. The utilization of N_2O.

M: Male; F: Female; TEP: Laparoscopic totally extraperitoneal inguinal hernia repair; TAPP: Transabdominal pre-peritoneal; N_2O: Nitrous oxide; CO_2: Carbon dioxide.

emphysema observed. Nonetheless, during the process of general anesthesia, if meticulous observation is not exercised, the symptoms of subcutaneous emphysema, and even pneumothorax, are highly likely to be masked, thereby potentially leading to delays in diagnosis and treatment. Due to the inherent difficulty in making a diagnosis based solely on clinical symptoms, pneumothorax often necessitates complementary imaging modalities for accurate detection [29]. In the present case, we employed chest X-ray examination to aid in the diagnosis. However, with the increasing prevalence of ultrasonography, chest ultrasonography has been shown to offer superior sensitivity in the diagnosis of pneumothorax compared to traditional X-ray techniques [30,31]. Furthermore, bedside pulmonary ultrasonography can be expeditiously performed, enabling real-time diagnosis of pneumothorax through the identification of four distinct ultrasonographic signs: vanishing pleural sliding, presence of lung points, disappearance of B-lines, and absence of lung pulse [32]. Therefore, it is imperative for clinical physicians to acquire proficiency in this technique through rigorous training and practice.

In clinical practice, anesthesiologists should exercise heightened vigilance during laparoscopic surgery in elderly patients, as this demographic is prone to more comorbidities, extended surgical durations, looser subcutaneous tissue, and more fragile connective tissue, which predispose them to an increased incidence of gas accumulation during pneumoperitoneum. Factors such as the intraoperative surgical approach, damage to the preperitoneal space and adjacent blood vessels, abrupt changes in airway pressure, elevated partial pressure of CO_2, and significant subcutaneous emphysema and pneumatosis can all precipitate severe complications. It is imperative that anesthesiologists remain cognizant of these potential issues throughout the surgical process.

4. Conclusion

In summary, although tension pneumothorax is a rare complication of laparoscopic inguinal hernia repair, it has the potential that can lead to fatal outcomes. In the context of critical scenarios, the ability to swiftly identify manifestations suggestive of pneumothorax during perioperative phases and to apply judicious interventions is of considerable importance. This highlights the significance of anesthesiologists prioritizing their attention on upcoming professional responsibilities.

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Ethical statement

Our study has been approved by the ethics committee of our hospital. Explicit informed consent was obtained from the patient to authorize the publication of this case report and its accompanying images.

Data availability statement

All data and materials described in the manuscript will be made available on request.

CRediT authorship contribution statement

Suting Liu: Writing – original draft. **Jing Chi:** Investigation, Data curation. **Hui Cao:** Investigation. **Xinggen Zhou:** Data curation. **Qingying Ma:** Formal analysis. **Yang Yang:** Investigation. **Jie Wang:** Writing – review & editing, Supervision. **Chao Zhang:** Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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