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Massive subcutaneous emphysema and the "sentinel hole" phenomenon after chest drain placement in neoplastic trapped lung: a case report from the emergency department

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Key words: blowhole technique; emergency medicine; malignant pleural effusion; subcutaneous emphysema; sentinel hole; trapped lung.

Abstract

Malignant pleural effusion may be complicated by non-expandable lung, a condition that increases the risk of iatrogenic complications during pleural drainage. A 91-year-old man developed massive subcutaneous emphysema after large-bore chest tube placement for malignant pleural effusion with non-expandable lung. Partial migration of the chest tube exposed proximal fenestrations to the subcutaneous tissue, creating a conduit for air propagation. Despite tube removal, emphysema progressed due to a persistent pleuro-cutaneous breach. Emergency decompression with multiple angio-catheters resulted in rapid clinical improvement. In non-expandable lung, the lack of pleural apposition prevents the drainage tract from sealing spontaneously, favouring persistent air leakage. Migration of chest tube fenestrations into soft tissues creates a low-resistance pathway for subcutaneous

emphysema. Early recognition of lung non-expandability and cautious drainage strategies are essential to prevent severe iatrogenic complications.

Introduction

Malignant Pleural Effusion (MPE) is a frequent complication of advanced malignancies and a common cause of acute dyspnoea in Emergency Departments. Standard management typically includes thoracentesis or tube thoracostomy for fluid drainage, often followed by pleurodesis.[1]

However, approximately 10-20% of patients with MPE develop a condition known as trapped lung, in which the lung parenchyma is unable to re-expand and occupy the thoracic cavity.[2] In this setting, chest drain placement is controversial and associated with a high rate of complications, including tube malfunction and iatrogenic subcutaneous emphysema. When severe, the latter may progress to a life-threatening condition requiring immediate decompressive interventions.[3]

Case Report

A 91-year-old man, independent in Activities of Daily Living (ADLs) and with a history of arterial hypertension, was referred to the Emergency Department of Cesena by his General Practitioner because of worsening exertional dyspnoea and pleuritic chest pain that had begun approximately one week earlier. On arrival at the ED (Day 1), the patient was alert and tachypnoeic (22 breaths/min) but hemodynamically stable. Physical examination of the chest revealed markedly reduced expansion of the left hemithorax, with absent breath sounds and dullness to percussion at the lung base. Bedside Thoracic Ultrasound (TUS) demonstrated a massive anechoic pleural effusion on the left, which was subsequently confirmed by Chest X-Ray (CXR). Routine laboratory tests were within normal limits, and the patient was admitted to the Emergency Department. An ultrasound-guided evacuative thoracentesis was performed, resulting in the removal of approximately 1700 mL of serosanguineous fluid. Pleural manometry was not available in the Emergency Department at the time of the procedure and therefore was not performed. The patient reported chest tightness and cough during drainage, however, these symptoms were initially interpreted as the result of rapid fluid evacuation rather than the consequence of an increased pleural elastance. Bedside TUS was used to identify the effusion and guide the puncture, but it was not applied to verify whether the procedure resulted in lung re-expansion. Pleural fluid analysis revealed an exudate (LDH 1750 U/L, total protein 4.9 g/dL) with a lymphocyte-predominant cell count. Cytological examination confirmed the presence of malignant cells consistent with adenocarcinoma during the same hospitalization. Post-procedural CXR revealed a persistent air-fluid level with the lung remaining collapsed at the hilum, a radiographic pattern consistent with ex vacuo pneumothorax in the setting of a non-expandable lung (Figure 1A). Given the persistence of symptoms (Day 2), a multidisciplinary discussion involving the surgical team led to the decision to place a chest drain (24 Fr) connected to a continuous suction system (−20 cmH_2O). Despite 36 hours of suction (Day 3) and the presence of a continuous air leak, the lung failed to re-expand and peri-tubular subcutaneous emphysema developed. A leak along the muscular tract was therefore hypothesized; accordingly, and in agreement with the surgeons, the chest drain was switched from suction to gravity drainage to reduce the transpleural pressure gradient. However, the subcutaneous emphysema had worsened. Inspection revealed partial dislodgement of the chest tube, with proximal fenestrations migrating into the subcutaneous tissue (Figure 1B). The drain was immediately removed. Over the following 24 hours (Day 4), despite removal of the tube, the emphysema progressed dramatically, extending to the neck, face (with eyelid closure), and the contralateral chest (Figure 1C). An urgent chest computed tomography (CT) scan demonstrated massive subcutaneous emphysema and persistence of a large left pleural chamber, with evidence of a chest wall breach at the previous insertion site (Figure 1D). To manage the massive subcutaneous emphysema, multiple 14G angio-catheters were inserted into the subcutaneous tissue using the "blowhole technique". This manoeuvre allowed rapid decompression of pressurized air and resulted in stabilization (Figure 2).

The patient was subsequently transferred to the Thoracic Surgery Department in Ravenna. After surgical revision of the chest wall breach and a two-week hospital stay, he was discharged with a definitive diagnosis of lung cancer. At discharge, the subcutaneous emphysema had completely resolved, while a stable chronic pneumothorax persisted. The sequence of clinical events is summarized in Table 1.

Discussion

This case illustrates the complexity of chest drain management in elderly patients with neoplastic disease and highlights the potentially dangerous interplay between underestimated pathological conditions, trapped lung, and the tube migration. We propose the term "sentinel hole phenomenon" to describe the situation in which migration of proximal chest tube fenestrations into the subcutaneous tissue creates a low-resistance conduit for air propagation from the pleural space into the fascial planes. To our knowledge, the specific mechanism of subcutaneous emphysema propagation related to proximal chest tube fenestration migration has rarely been described in the emergency medicine literature.

The first trigger in this case was the failure to recognize lung non-expandability in a timely manner. The literature distinguishes lung entrapment (an active, potentially reversible constrictive effect) from trapped lung, which represents a chronic condition where an inert fibrous peel or diffuse pleural carcinosis "encases" the lung, rendering it unable to re-expand.[4] Early recognition of non-expandable lung through pleural manometry or systematic post-procedural ultrasound reassessment might have prevented the subsequent management decisions that led to the complication.

In our patient, the application of negative pressure via suction drainage (-20 cmH_2O) to a lung with high elastance generated a significant barometric imbalance. According to Boyle's law, an increase in pleural cavity volume following fluid evacuation without lung re-expansion cause a decrease in intrapleural pressure, which may reach values below -40 cmH_2O. This condition, known as *ex-vacuo* pneumothorax, exerts continuous traction on the chest wall, preventing closure of the drainage tract and maintaining parenchymal fistula patency.[5,6] In patients with trapped lung, physiological pleural apposition never occurs, leaving a residual space communicating with the external environment. An additional diagnostic tool that may help identify non-expandable lung during thoracentesis is pleural manometry. By measuring pleural pressure during fluid removal, pleural manometry allows real-time assessment of the pressure-volume relationship and pleural elastance, which may reveal an abnormal pressure drop suggestive of non-expandable lung. Although pleural manometry is not routinely performed in many clinical settings and lacks widespread standardization, several studies suggest that it may provide useful physiological information and help prevent complications such as *ex-vacuo* pneumothorax during large-volume thoracentesis.[7,8]

Geriatric-specific predisposing factors, such as intercostal sarcopenia and subcutaneous laxity, facilitated the distal migration of the chest drain. When the most proximal fenestration of the catheter migrates from the pleural cavity into the subcutaneous tissue, a functional bypass is created. Rather than evacuating air externally, the tube becomes a low-resistance conduit that channels air directly from the pleural space into the fascial planes. A possible mechanism is that transient increases in intrathoracic pressure during coughing or Valsalva manoeuvres facilitated air leakage through the pleuro-cutaneous tract. The literature confirms that this complication is significantly more frequent in patients with trapped lung than in those with free-flowing pleural effusions, primarily because of the persistence of a residual pleural space that acts as an inexhaustible air reservoir.[8] Furthermore, the persistent pleuro-cutaneous breach after tube removal dramatically fuelled emphysema progression. Absent pleural apposition prevents biological sealing of the defect, and transient increases in expiratory pressure force air through frail geriatric tissues.[9] Rapid extension into the deep cervical and mediastinal planes may mimic a compartment-like syndrome, with potential risks of tracheal compression, carotid baroreceptor dysfunction, and skin ischemia or necrosis due to excessive tissue tension. The Aghajanzadeh score classifies subcutaneous emphysema into five severity grades (Grade 1: air is localized to the base of the neck; Grade 2: Air involves all the neck area; Grade 3: air extends to the subpectoral is major area; Grade 4: air involves the chest wall and the entire neck area; Grade 5: massive involvement including the chest wall, neck, scalp, abdominal wall, upper limbs, and scrotum). Rapid extension into deep cervical planes (corresponding to Grade 4, as observed in our patient) mimics a compartment-like syndrome, risking tracheal compression and skin ischemia.[10,11] While mild forms (Grades 1-2) generally benefit from conservative management with high-flow oxygen therapy to promote nitrogen washout, severe cases require active decompression. The blowhole technique with angio-catheters provided rapid tension relief and remains the preferred emergency option.[12]

Retrospective analysis underscores the inappropriateness of the initial drainage strategy. Joint guidelines (ATS/STS/STR) recommend a personalized approach utilizing prognostic tools like the LENT score.[13] Our patient had a LENT score of 5, calculated as follows: pleural LDH 1750 U/L (1 point), ECOG performance status 1 (1 point), neutrophil-to-lymphocyte ratio >9 (1 point), and high-risk tumour histotype (lung cancer, 2 points). This places the patient in the high-risk LENT category, associated with a median survival of approximately 1-3 months.[14] In this clinical context, pursuing complete lung re-expansion with rigid, large-bore drains (24 Fr) connected to suction (despite British Thoracic Society guidelines advocate for small-bore tubes) is often ineffective and harmful.[2,15] Evidence from the TIME2 trial supports the use of Indwelling Pleural Catheters (IPC) as a first-line strategy in patients with NEL and limited life expectancy. IPCs allow symptom-guided fluid evacuation without continuous suction and reduce the risk of mechanical complications.[16]

Because of the limited availability of pleural manometry, the bedside M-mode TUS is of significant clinical and educational value as a pre- and peri-procedural non-invasive tool. Specifically, the M-mode detection of an absent sinusoidal sign and reduced atelectatic lung movement are hallmarks of trapped lung. Implementing M-mode TUS assessment as a preliminary step in cases of suspected NEL could bridge current diagnostic gaps, though diagnostic cut-offs and inter-operator variability require further validation.[17,18] Looking further ahead, improving the early diagnosis of NEL will likely rely on multimodal integration, combining bedside TUS with digital pleural manometry. Ultimately, artificial intelligence-assisted image analysis (including automated detection of the absent sinusoidal sign, quantification of lung strain, and echogenicity-based predictive models) represents the future for reducing operator dependency and enabling early, individualized therapeutic decisions in MPE patients.[19] Another important aspect concerns the choice of drainage strategy. Compared with large-bore chest tubes, small-bore catheters (10-14 Fr) show similar efficacy with lower complication rates for malignant pleural effusion as indicated by guidelines and several meta-analyses.[15] In our case, a 24 Fr chest tube was inserted due to concerns about possible obstruction related to the viscosity of serosanguineous pleural fluid. Retrospectively, the use of a smaller-bore catheter would have been more appropriate, particularly in a very elderly patient with fragile subcutaneous tissues. Furthermore, continuous suction (-20 cm H_2O) was applied to promote lung re-expansion. However, in the presence of NEL, suction may increase pleural pressure gradients and favour persistent air leakage through the drainage, thereby facilitating subcutaneous emphysema.

Conclusions

The clinical course of this case raises critical questions regarding decision-making algorithms for massive pleural effusions in the ED. Current guidelines emphasize a personalized approach guided by lung expandability and prognosis.[13,15] In suspected trapped lung, standard large-bore chest drainage intended for pleurodesis is associated with high failure rates and mechanical complications.[3] Age-related tissue fragility predisposes to persistent pleuro-cutaneous breaches and massive subcutaneous emphysema. IPCs represent an effective alternative in the high-risk LENT category.[16] Finally, in patients with suspected NEL, a more conservative initial drainage strategy, ideally guided by pleural manometry, may help reduce the risk of *ex-vacuo* complications.[5,6]

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Table 1. Timeline of clinical events during hospitalization.

Day	Event
Day 1	Admission, thoracic ultrasound, thoracentesis (1700 mL)
Day 2	Persistent symptoms → chest tube placement (24 Fr, suction −20 cm H_2O)
Day 3	Persistent air leak and worsening of subcutaneous emphysema
Day 4	Tube removal, computed tomography scan, emergency decompression (blowhole technique)

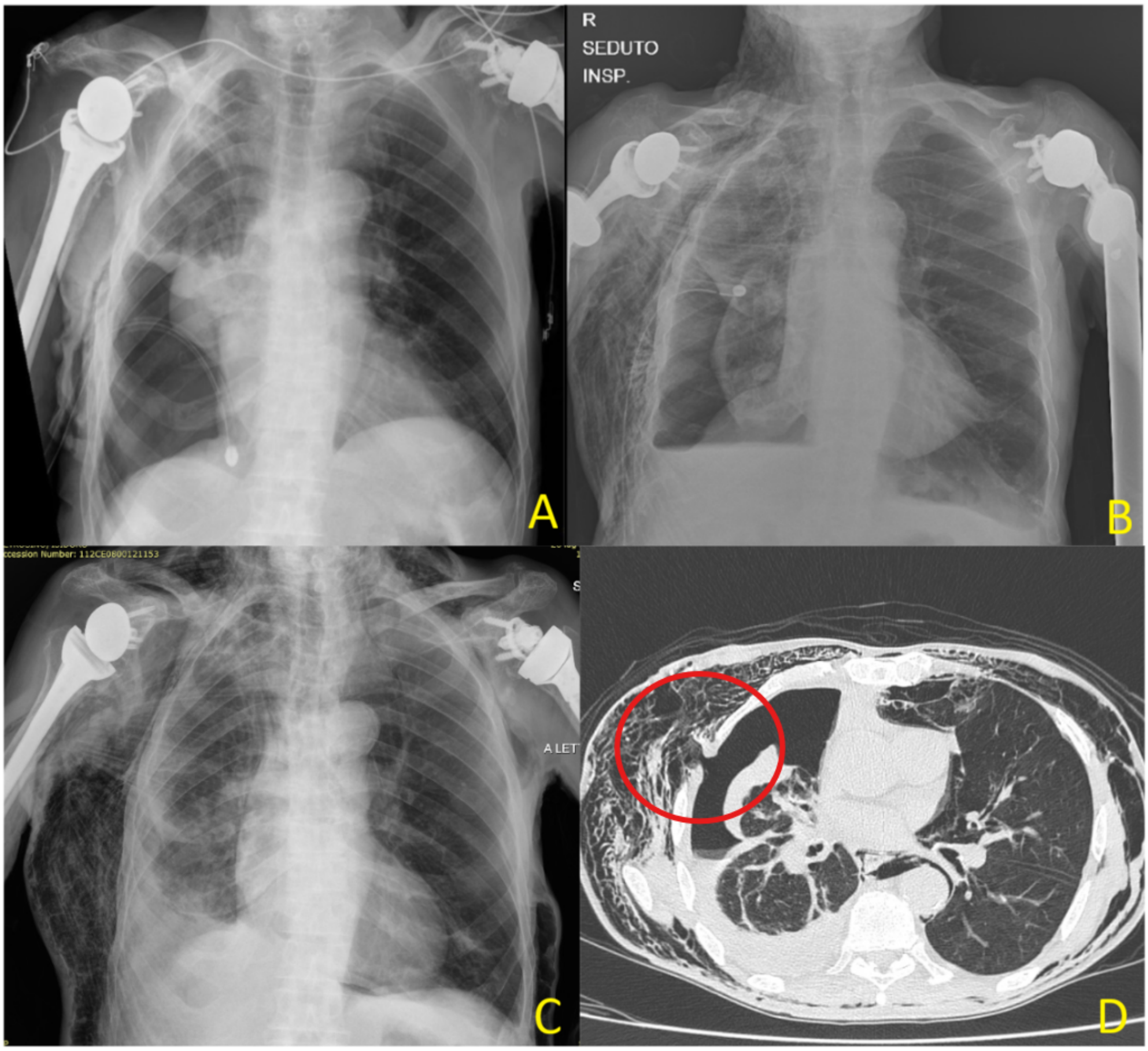

Figure 1. Radiological evolution of chest drainage-related complications. A) Chest X-ray (CXR) obtained after chest drain placement, showing a persistent air-fluid level consistent with non-expandable lung; B) CXR performed 36 hours later, demonstrating migration of the proximal drainage fenestrations into the subcutaneous tissue; C) CXR after chest drain removal, showing marked progression of subcutaneous emphysema; D) Chest Computed Tomography (CT) scan highlighting massive subcutaneous emphysema and a chest wall breach at the previous drain insertion site (red circle).

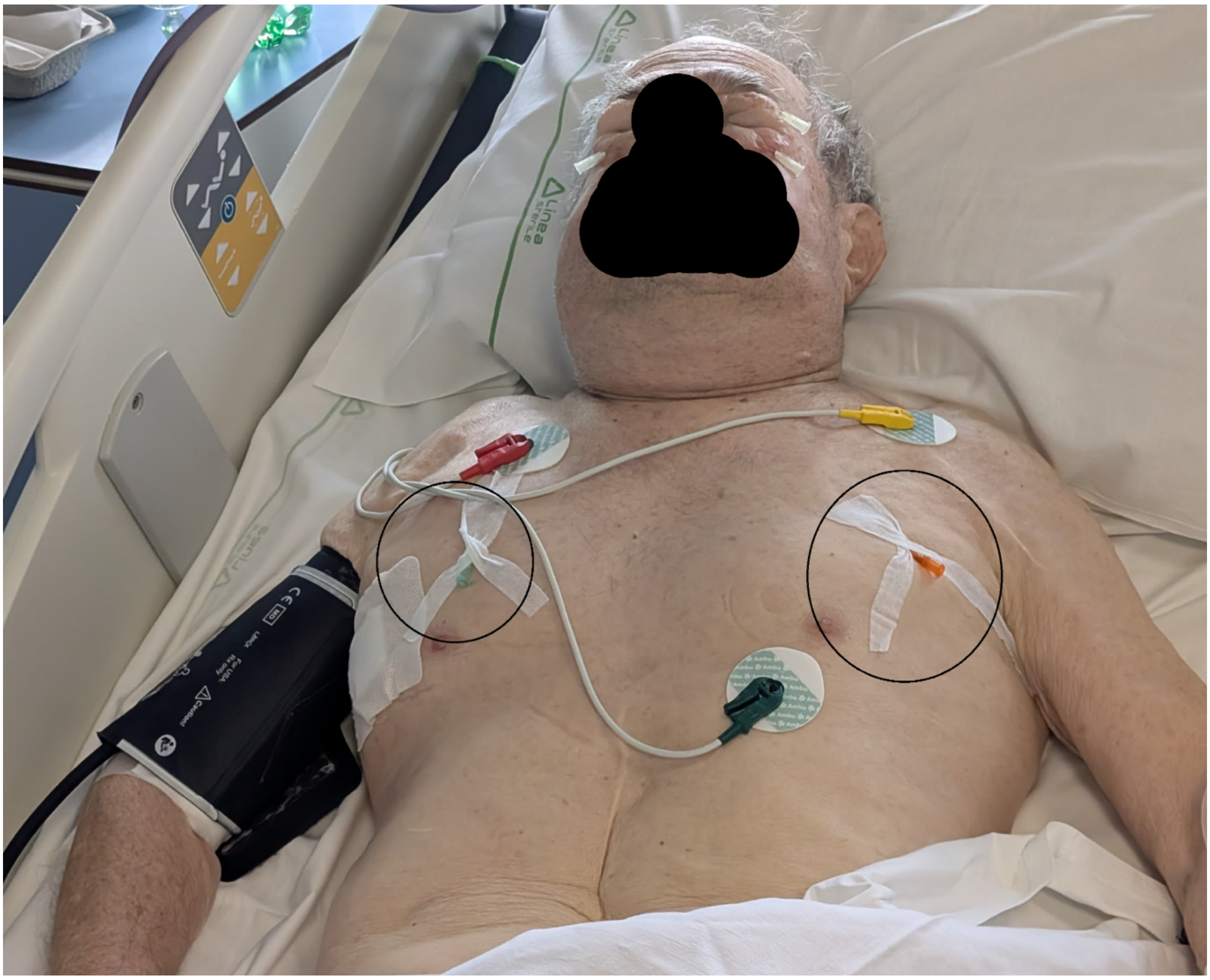

Figure 2. Emergency decompression of massive subcutaneous emphysema using the blowhole technique. Multiple 14G angio-catheters were inserted into the subcutaneous tissue of the anterior chest wall (circled), allowing the release of pressurized air and resulting in rapid clinical stabilization.

Contributions: Alessandro Rapino, and Matteo Bolognesi designed the project and wrote the paper. Alessandro Rapino, Matteo Bolognesi, Michela Cascio, Giuseppe Romano, and

Raffaella Francesconi searched the literature for retrievable papers. Roberto De Giorgio and Matteo Guarino critically reviewed the paper. All authors have read and agreed to the published version of the manuscript.

Ethics approval: according to local institutional policies for retrospective case reports involving a single patient and no experimental intervention, a formal ethical approval was not required. The study was therefore considered exempt from full ethical review.

Informed consent: obtained and available on reasonable request.

Availability of data and materials: all data underlying the findings are fully available in the present paper.

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