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PRACTICAL APPROACH

A Practical Approach to Pneumothorax Management

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ABSTRACT

Pneumothorax, defined by the presence of air in the pleural cavity, is a potentially life-threatening condition requiring prompt diagnosis and tailored management. Rapid and accurate diagnosis is primarily achieved through radiological imaging. Management strategies for pneumothorax vary according to severity and aetiology. Conservative care, involving vigilant observation and supplemental oxygen, is suitable for small, stable pneumothoraxes. Needle aspiration can be an effective first-line treatment, although it may fail in some instances, necessitating escalation. Ambulatory devices facilitate outpatient care and reduce the length of hospital stays. Chest drainage remains a cornerstone therapy. Indwelling pleural catheters may be implemented in selective cases. Endobronchial treatments, including valves and spigots, offer minimally invasive options for reducing the flow of air leaks. Medical thoracoscopy with talc poudrage provides both diagnostic and therapeutic benefits in patients unsuitable for surgery, while surgical intervention represents the gold standard for definitive treatment. Adjunctive interventions include talc slurry pleurodesis and autologous blood patch pleurodesis for patients unsuitable for surgery. Effective management necessitates individualized treatment plans, incorporating risk factor modification, pain management, and physiotherapy. This practical approach aims to update the reader on the treatment modalities that can be used in all forms of pneumothorax in clinical practice.

Keywords: Pneumothorax; Drainage; Thoracoscopy; Talc; Blood patch; Physical therapy

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Key Summary Points

Classification and diagnostic modalities: Pneumothorax is categorized into spontaneous, traumatic, and iatrogenic variants. Its diagnosis relies on a spectrum of imaging techniques, including chest radiography, computed tomography (CT), point-of-care ultrasound (POCUS), and, in select cases, fluoroscopy.

Conservative management: In cases of small, clinically stable primary spontaneous pneumothorax, conservative management—entailing clinical and radiological observation combined with oxygen therapy—has proven effective in facilitating the reabsorption of intrapleural air while minimizing the risks associated with invasive interventions.

Minimally invasive interventions: Needle aspiration is an effective intervention for moderate-sized pneumothoraces; however, procedural failure may necessitate escalation to more invasive treatments such as intercostal chest drainage. The integration of ambulatory devices has also enabled the outpatient management of selected cases, thereby reducing the duration of hospitalization.

Adjunctive therapies: For patients in whom surgical intervention is contraindicated, adjunctive therapies such as talc slurry pleurodesis and autologous blood patch pleurodesis can be employed. Furthermore, the utilization of indwelling pleural catheters and endobronchial techniques (e.g. valve or spigot placement) offers additional minimally invasive treatment options.

Surgical intervention: Video-assisted thoracoscopic surgery (VATS) is primarily reserved for recurrent, complicated, or persistent cases of pneumothorax. This surgical approach enables definitive management through the resection of blebs or bullae and the application of pleurodesis techniques, thereby reducing the risk of recurrence and addressing high-flow air leaks effectively.

INTRODUCTION

Pneumothorax is characterised by the presence of air within the pleural cavity and represents a potentially life-threatening condition requiring prompt and wise clinical management. Its classifications encompass spontaneous, traumatic, and iatrogenic varieties, with further classification of the spontaneous ones into primary spontaneous pneumothorax (PSP) and secondary spontaneous pneumothorax (SSP) based on either the absence or presence of an underlying lung disease (Table 1) [1]. An accurate and timely clinical and radiological diagnosis followed by treatment based on both evidence and clinical experience are decisive acts to mitigate morbidity and prevent both relapses and potentially fatal complications.

This article is based on reviews of current guidelines and literature and did not involve any new studies with human participants or animals performed by any of the authors. Written informed consent was obtained from all patients depicted in the clinical cases and respective images.

METHODOLOGY OF THE REVIEW

Given the narrative nature of this review, the selection of references was primarily informed by the authors' existing knowledge and familiarity with the literature. Relevant articles were identified based on their perceived significance, historical relevance, and practical impact on the topic under discussion, rather than through a systematic search strategy. Of note, the list of included references is not necessarily all-encompassing but reflects the body of evidence believed appropriate to the purpose of this document: highlighting the most practical solutions for the management of pneumothorax.

DIAGNOSTIC TOOLS

The diagnosis of pneumothorax relies heavily on radiological imaging, which offers vital details

Table 1 Etiologies of secondary spontaneous pneumothorax (SSP)

Aetiology	Description
Chronic obstructive pulmonary disease (COPD)	The most common cause of SSP; due to rupture of bullae or blebs in emphysematous lungs
Cystic fibrosis	Associated with bronchiectasis and pulmonary infections, leading to structural lung damage
Pulmonary tuberculosis	Cavitary lesions and necrosis can predispose to air leaks and pleural rupture
Pulmonary abscess	Localised infection with tissue necrosis may erode into pleural space, causing pneumothorax
Pneumocystis jirovecii pneumonia (PJP)	A form of infectious pneumonia that occurs mainly in immunocompromised individuals and is associated with the formation of lung cysts
Interstitial lung disease (ILD)	Fibrosis and honeycombing in diseases such as idiopathic pulmonary fibrosis increase the risk fo spontaneous pneumothorax
Sarcoidosis	Granulomatous inflammation may cause cavitation and predispose to SSP
Connective tissue diseases	Conditions such as rheumatoid arthritis and systemic sclerosis can lead to excavating nodules or ILD
Langerhans cell histiocytosis	A smoking-related disease manifesting as cystic lung alterations
Lymphangioleiomyomatosis (LAM)	A rare disease; characterised by cystic lung changes leading to pneumothorax
Birt–Hogg–Dubé syndrome	A rare genetic disorder causing multiple lung cysts and specific dermatological lesions
Neoplasms (primary or metastatic)	Tumour invasion into the pleura or airways can result in pneumothorax
Asthma	Severe asthma exacerbations may lead to air trapping and alveolar rupture
Catamenial pneumothorax	A spontaneous pneumothorax occurring within 72 h before or after onset of menstruation, frequently associated with thoracic endometriosis
Pulmonary infarct	Necrosis of lung tissue due to impaired blood supply may result in structural compromise and pneumothorax

regarding the location, size, and presence of air in the pleural cavity [2]. Because of its affordability and availability, chest X-ray continues to be the first and most widely used modality among the various options [2]. Posteroanterior and lateral view radiographs are routinely utilised, with the hallmark radiological sign of pneumothorax being the presence of a visceral pleural line that does not extend to the chest wall, accompanied by the absence of lung markings peripheral to this line [2]. In certain cases, an expiratory chest radiograph may enhance the visibility of small pneumothoraxes by increasing the contrast between the lung and the pleural air [3].

In instances where chest radiography yields inconclusive findings or when a more detailed assessment is required, computed tomography (CT) serves as the gold standard [4]. CT offers superior sensitivity and specificity, enabling the detection of small pneumothoraxes, subtle pleural abnormalities, and associated pathological conditions such as emphysematous bullae or trauma-related injuries [4]. Its three-dimensional imaging capability is particularly beneficial in identifying loculated pneumothoraxes or those in anatomically complex regions [5, 6]. However, the use of CT is typically reserved for patients with atypical presentations, preprocedural evaluations, or when complications are suspected, due to its higher cost and radiation exposure [5, 7].

Pneumothorax can be quickly diagnosed at the patient's bedside with point-of-care ultrasound (POCUS), especially in emergency and critical care settings [8–10]. The absence of lung sliding, the lack of B-lines, and the existence of a lung point, which denotes the interface between the aerated and collapsed lung, are important sonographic indicators [11]. Although technical constraints and operator dependence continue to be issues, POCUS is becoming more widely acknowledged for its great sensitivity and usefulness in cases requiring urgent imaging or in clinically unstable patients. Ultrasound allows an area of interest, such as an air sac, to be identified in real time [12].

Fluoroscopy can also be a valuable diagnostic tool for detecting iatrogenic pneumothorax during interventional procedures in which it is implemented, offering real-time imaging to identify pleural air accumulation [13]. Its dynamic nature enables immediate visualization of lung collapse or diaphragmatic movement abnormalities. The unfavourable aspect of the technique is the need to interpret numerous artefacts [14].

When combined, these radiologic methods allow rapid and accurate diagnosis and estimation of the volume of the air in the pleural cavity, which promotes the initiation of the best possible treatment of pneumothorax.

MANAGEMENT

Conservative Care

Conservative management represents a recognised therapeutic alternative for appropriately selected cases of pneumothorax, particularly in small and clinically stable PSPs with minimal or no symptoms, while it is an inadvisable choice in cases of SSP and traumatic pneumothorax except for selected cases [15–19]. This strategy entails vigilant clinical and radiological observation, permitting the natural resolution of the pneumothorax through pleural air reabsorption [17]. Administering high flow (10 L/min) supplemental oxygen may expedite the healing process by enhancing the rate of air reabsorption by a multiple of four [20]. Conservative management minimises the risks associated with invasive interventions and demonstrates cost-effectiveness [17]. Rigorous patient selection is imperative, ensuring the exclusion of secondary causes or complications already present at the time of diagnosis. Escalation to active interventions is reserved for cases of clinical deterioration or inadequate resolution.

Needle Aspiration

Aspiration is a widely utilised treatment for pneumothorax, particularly in cases of PSP, in clinically stable patients with moderate-sized air accumulation [21]. The procedure involves inserting a fine-bore needle or catheter into the pleural space to manually evacuate air and facilitate lung re-expansion [22]. Aspiration should be performed under local anaesthesia and can be guided by ultrasound imaging findings to ensure accurate needle placement [23]. Its efficacy depends on achieving adequate lung re-expansion, with subsequent monitoring to detect recurrence, which occurs in nearly 30% of cases [24] (Fig. 1). Progressive lung re-expansion may be monitored via POCUS and confirmed radiologically with a chest X-ray. Aspiration is favoured for its simplicity, enhanced patient comfort, and avoidance of hospitalization compared to more invasive interventions [17].

Aspiration may fail, as defined based on clinical, radiological, and procedural criteria, necessitating escalation to alternative treatments such as chest tube insertion. Clinically, the persistence or worsening of symptoms such as dyspnoea, chest pain, or hypoxia after aspiration suggests treatment failure. Radiologically, failure is identified if post-procedural imaging, usually a chest X-ray, shows persistent air (> 2 cm) in the pleural cavity despite aspiration, particularly with persistent respiratory symptoms [24]. From a procedural perspective, aspiration is deemed unsuccessful if air cannot be effectively evacuated, such as in the presence of a persistent air leak, which is often indicative of underlying pleural or lung disease. Other contributing factors to failure may include improper needle placement or significant pleural adhesions. Recognising the criteria for aspiration failure promptly is crucial to prevent prolonged morbidity. Patients identified as high risk or experiencing recurrent pneumothoraxes often benefit from early escalation to more definitive interventions, such as chest tube thoracostomy or surgical management. The expected yearly recurrence rate for aspiration in PSP is 15% [25].

Aspiration may, on a case-by-case basis, also be applied in SSP [26], iatrogenic [27, 28] and traumatic [29] aetiologies, or in patients with isolated residual air pockets, particularly in cases previously managed by other invasive methods but remaining symptomatic or displaying altered vital signs despite optimisation of other variables. Radiographic evidence of a significant, percutaneously accessible air pocket in a symptomatic patient is a key indication. Notably, following pleurodesis procedures, the lung parenchyma may fail to fully re-expand in certain areas despite the absence of atelectasis. Even a small volume of non-expanded parenchyma, especially in patients with severely compromised lung architecture, can contribute to persistent symptoms. In such cases, aspiration may offer a targeted approach to alleviate residual symptoms and improve clinical outcomes (Fig. 2).

Ambulatory Devices

Ambulatory devices have revolutionised the management of pneumothorax by enabling treatment in outpatient settings, reducing the length of hospital stays, and enhancing patient mobility [30, 31]. Portable devices, such as one-way valve systems (e.g. Heimlich valves, all-in-one systems) or small-bore chest drains connected to lightweight collection systems, facilitate continuous air evacuation from the pleural cavity while allowing patients to remain walking active without the encumbrance of large collection chambers [32, 33] (Fig. 3). These systems are particularly useful in the setting of acute stable cases of spontaneous or iatrogenic pneumothorax [32], and to reduce the length of stay in cases of postoperative pneumothorax or those with long-term residual air leakage [34, 35]. The design of these systems prioritises ease of use, patient comfort, and safety. However, the complication rate associated with this management modality is not negligible, especially for SSP, and needs to be discussed with the patient [36]. Ambulatory management can thus represent a cost-effective and patient-centred approach to pneumothorax care, but needs a standardised patient education protocol and the scheduling of an outpatient follow-up regime [37].

Chest Drainage

Chest drainage is the historical cornerstone therapy for pneumothorax, offering immediate decompression of the pleural space and a safe route of air egress from the pleural cavity. This intervention involves the insertion of a chest tube connected to an underwater seal, with or without suction to evacuate air [38]. It is particularly effective in managing persistent air leaks. Chest drainage is often employed as

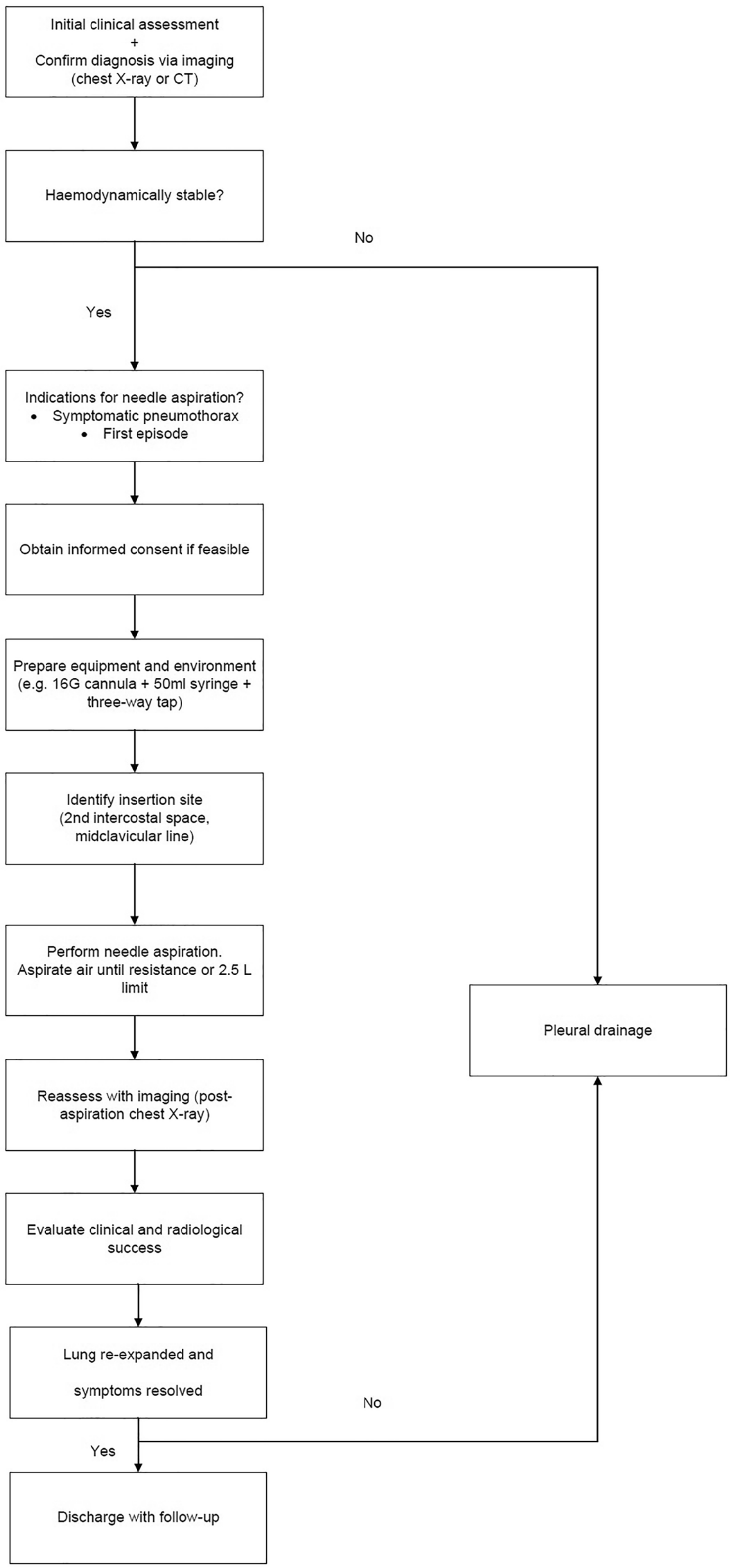


Fig. 1 Procedural flow chart related to pleural aspiration with needle or cannula. *CT* computed tomography

a standalone treatment or as a bridge to more definitive interventions, such as pleurodesis or surgery [39]. Proper tube placement and ongoing monitoring are critical to minimising complications and ensuring therapeutic success.

The choice of chest tube lumen size in pneumothorax management depends on clinical presentation, pneumothorax aetiology, and patient factors. Small-bore catheters (10–14 Fr) are often preferred for uncomplicated PSP owing to lower associated pain and discomfort levels [40]. Larger-bore tubes (>20 Fr) are reserved for SSP, traumatic pneumothorax, or when high-flow air leaks or associated dense fluid collections are anticipated [41].

In most cases, immediately after placement, it is preferable to place the pleural drainage in gravity, without suction, to prevent the formation expansion pulmonary oedema [42].

Talc Slurry Pleurodesis

Talc slurry pleurodesis is a widely utilised and effective method for the management of SSP in patients not suitable for surgical intervention [43]. The procedure involves the instillation of sterile talc (4 g) suspended in saline or local anaesthetic through a chest drain to induce pleural inflammation and adhesion [43, 44] (Fig. 4). Special attention should be paid to analgesic therapy in this context, as the parietal pleura is extensively innervated—pleurodesis can thus cause intense pain and not infrequently autonomic reflexes.

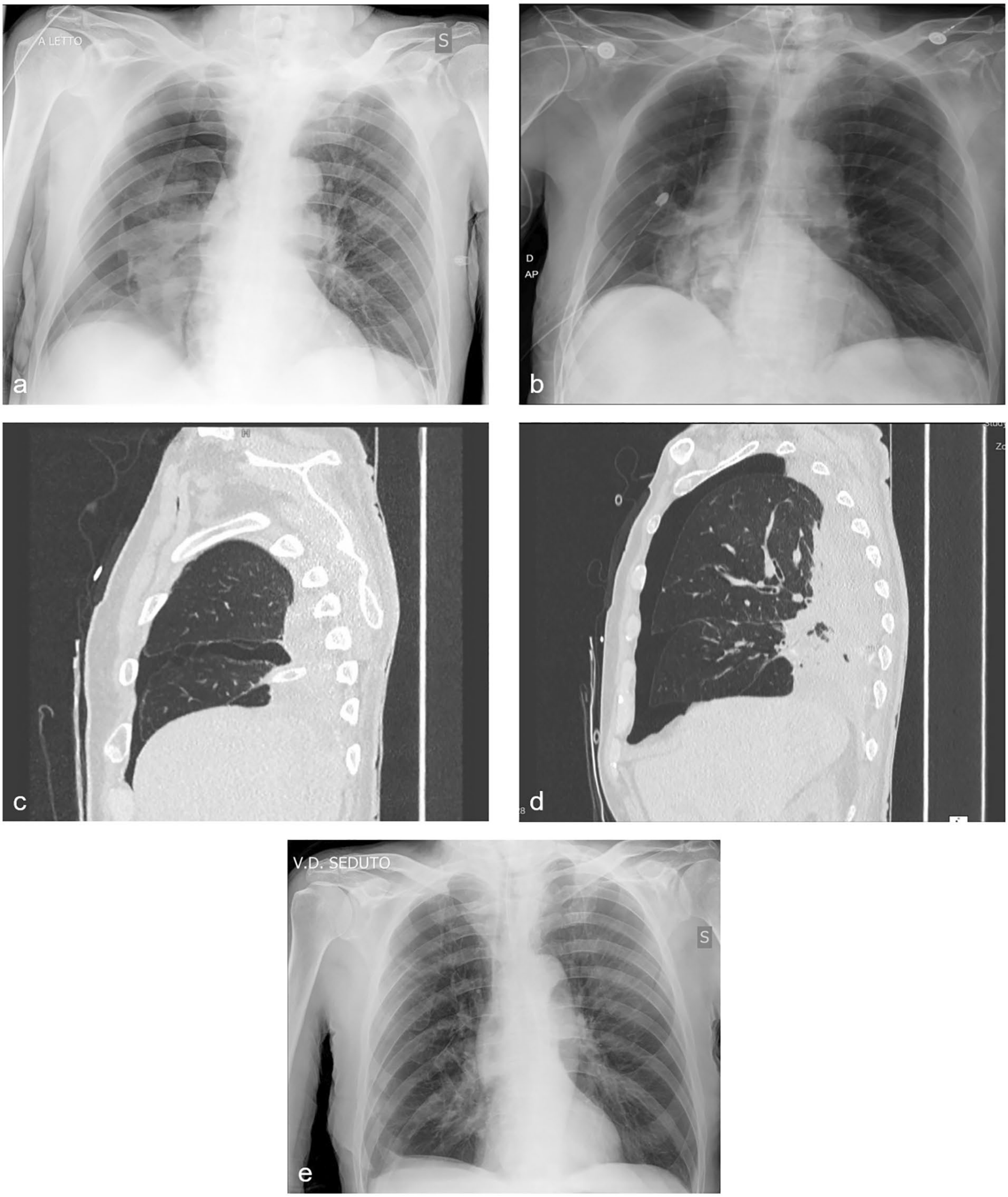
In patients with pneumothorax, particularly those with persistent air leaks, this pleurodesis protocol requires specific modifications compared to its use in malignant pleural effusions. Clamping the chest drain is contraindicated because of the risk of tension pneumothorax. Instead, a loop is created by elevating the drainage tubing above the insertion site, ensuring the talc solution remains within the pleural cavity while permitting continuous air evacuation [45]. This technique allows effective distribution of the talc on the pleural surface without compromising safety. This technique aims to induce pleural inflammation and fibrosis, effectively obliterating the pleural space while inducing pleural adherences to prevent a symptomatic recurrence [46] (Fig. 5).

Blood Patch

Autologous blood patch pleurodesis (ABPP) is another alternative for patients who are not candidates for surgery. The commonly used protocol is by Rinaldi et al., whereby 100 mL of the patient's blood is withdrawn, inserted into the pleural cavity via the chest tube, and then the tube itself is looped over a stand as in the talc slurry procedure [47]. The chest tube is monitored for ongoing signs of an air leak, and the procedure can be repeated if the air leak is not settling (Fig. 6). The recent British Thoracic Society (BTS) pleural disease guidance and pleural procedures statement both corroborate its application as a procedure aimed at shortening the length of stay [48, 49]. The mechanism of action of ABPP is presumed to be due to a blood-induced inflammatory response, which induces pleurodesis as well as a patch effect, with the blood instilled clogging up the pleural defects [50]. As a result of those proposed mechanisms, the expert opinion would also suggest that there is no need for pleural apposition (in direct contrast to the use of talc slurry where more than 75% of pleural apposition is required) [51]. Success rates of air leak cessation are between 50% and 80% [52, 53].

Indwelling Pleural Catheter

The positioning of an indwelling pleural catheter (IPC) is a recently proposed approach for managing recurrent or persistent pneumothorax in patients unfit for surgery. The procedure involves placing a tunnelled catheter into the pleural cavity and connecting it to a one-way valve device [54], allowing continuous air evacuation while simultaneously allowing a pleurodesis treatment to be performed at a later time [55]. Typically, placement of this device occurs during hospitalization as a replacement for a chest tube already in place. This solution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◂**Fig. 2** Management of SSP by thoracic drainage followed by pleural aspiration. **a** Radiological demonstration of a right pneumothorax on chest X-ray. **b** Chest tube placement with partial lung expansion. **c** Thoracic tomographic evidence of occluded and trapped drainage in scissural location. **d** Evidence of persistent anterior pneumothorax (patient in supine decubitus) with size over 2 cm in a symptomatic patient requiring high oxygen flows. **e** Treatment outcome after thoracic drain removal and manual suctioning of the anterior residual pneumothorax with a catheter; evidence of complete lung expansion. *SSP* secondary spontaneous pneumothorax

enables discharge and outpatient management, enhancing patient comfort while reducing the length of stay. However, the calibre of the currently disposable devices is small and does not allow high airflow to pass through. In addition, the evidence is mainly based on case reports in highly complex cases of patients with multiple comorbidities [56].

Thoracic Suction and Chest Drain Clamping

After pleurodesis-targeted treatments a high volume, low pressure (between −10 and −20 cmH_2O) thoracic suction system can be used in patients with pneumothorax to promote visceral and parietal lung apposition. Theoretically, this should promote healing of the pleural defect in pneumothoraces and allow talc slurry to be performed [49] if indicated, and can be applied after pleurodesis as well to promote pleural apposition. However, robust evidence for suction does not exist—the only randomised controlled trial to date showed no difference in outcomes with suction [57]. Digital suction devices such as Thopaz+ [58] have been used for a number of years, mostly in the postoperative setting, and the National Institute for Health and Care Excellence in the UK [59] has recommended their use to reduce length of stay for patients with pneumothorax. Their use shows promise, but further research into their effectiveness is warranted.

Clamping of the chest drain prior to removal, as part of the decision-making at the time of probable air leak cessation, again does not have a robust evidence base [60]. Previous clamping studies are single-centre and observational, with limited general applicability. There is wide variability in clamping amongst physicians [61], and the 2023 BTS pleural disease guidance mentions that clamping should be studied further. A recent study by Veale et al. showed that pneumothorax recurrence (presumably due to non-cessation of air leak) and need for further intervention at 30 days after chest drain removal was not different with clamping [62].

Endobronchial Treatment

Endobronchial treatments, including spigots and valves, have emerged as innovative approaches for managing pneumothorax, particularly in patients with persistent air leaks or those unfit for surgical intervention [63]. Endobronchial one-way valves, such as the Zephyr or Spiration valves, are placed via bronchoscopy to selectively occlude the segments afferent to lung lacerations or air-supplying bullous areas, facilitating pleural healing and lung re-expansion [64]. Silicone spigots are similarly employed to block affected airways, effectively reducing air leaks [65]. Even treatments based on biological material, such as the endobronchial autologous blood patch, have been proposed [66]. These minimally invasive methods are especially beneficial in complex cases, such as SSP or postsurgical leaks, but the evidence comes often from observational case series.

Their placement can be guided using specialized devices, such as the Chartis system, which confirms a persistent flow of air from the segments affected by the pathology or identifies the negative pressure generated by the vacuum applied to the chest tube in both the inspiratory and expiratory phases [67, 68]. Alternatively, sequential balloon occlusion of different bronchial segments, combined with observation of reduced airflow in the chest drainage collection chamber, enables endoscopic identification of the bronchial branch contributing to the persistent air leak [68]. This precise localization facilitates targeted intervention, enhancing the effectiveness of the procedure. Recently, a comprehensive document of best

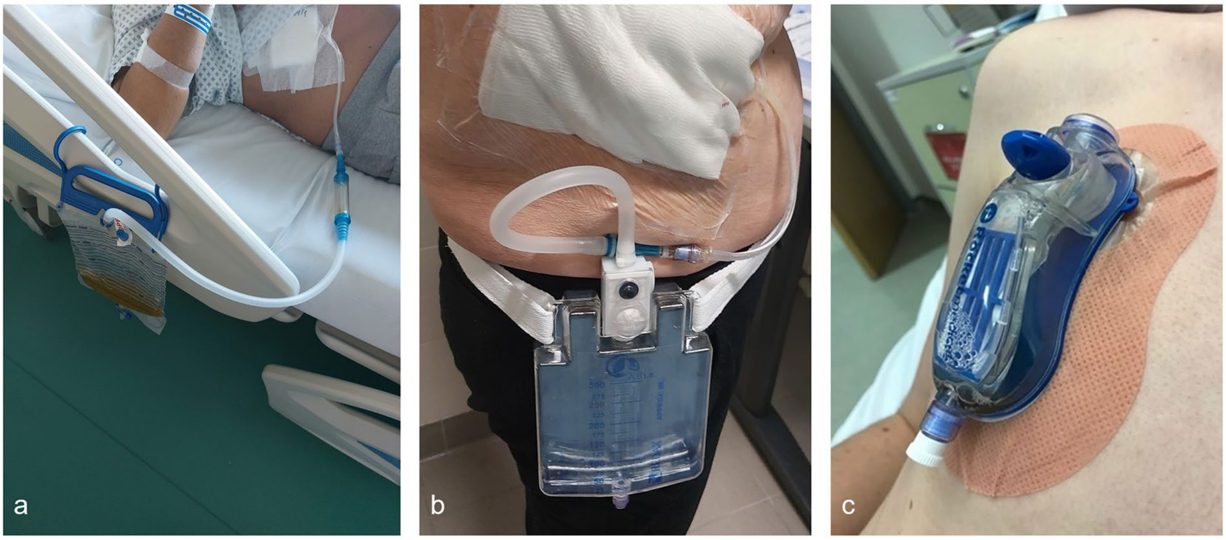


Fig. 3 Devices for the ambulatory management of pneumothorax with or without associated pleural fluid. **a** Traditional Heimlich valve with collection bag in a patient with malignant pleural effusion and a large broncho-pleural fistula both treated with an IPC. **b** Solid collection chamber with an associated one-way valve (Redax® Drentech WearABLE™) attached to an IPC. **c** All-in-one device with built-in one-way valve (Rocket® Pleural Vent™). *IPC* indwelling pleural catheter

practice recommendations has been published, providing detailed guidelines on the optimal use of these techniques for managing persistent air leaks [69].

Endobronchial treatments serve as a valuable adjunct to pleural drainage and pleurodesis interventions by significantly reducing airflow through the pulmonary breach, thereby promoting healing and facilitating lung re-expansion. These devices are typically retained for several weeks or months, depending on the patient's clinical progress, until the risk of pneumothorax recurrence is deemed acceptably low.

Despite their benefits, endobronchial valves and spigots can cause adverse effects, including infection, granulation tissue formation, valve migration, airway obstruction, or exacerbation of underlying pulmonary conditions, necessitating careful monitoring [68].

Medical Thoracoscopy with Talc Poudrage

Medical thoracoscopy, also known as pleuroscopy, can be used in the management of pneumothorax, offering a minimally invasive approach under local anaesthesia and preferably sedation to maximise the patient's comfort [70] (Fig. 7). It allows direct visualisation of the pleural cavity, enabling the identification of pleural abnormalities, such as blebs, bullae, or pleural adhesions, which are often implicated in pneumothorax pathogenesis. Therapeutically, medical thoracoscopy facilitates interventions such as pleurodesis, especially using talc poudrage [70]. Its minimally invasive nature makes it particularly advantageous for patients unsuitable or unwilling to undergo classical surgical thoracoscopy.

The pleural drainage placed at the end of the procedure, usually of large calibre, monitors air leaks in the days following the procedure, additionally allowing further treatments to be carried out if necessary (e.g. talc slurry or ABPP).

Surgical

Surgical treatment is the cornerstone treatment modality in managing recurrent, persistent, or complicated cases of pneumothorax. Video-assisted thoracoscopic surgery (VATS) is the

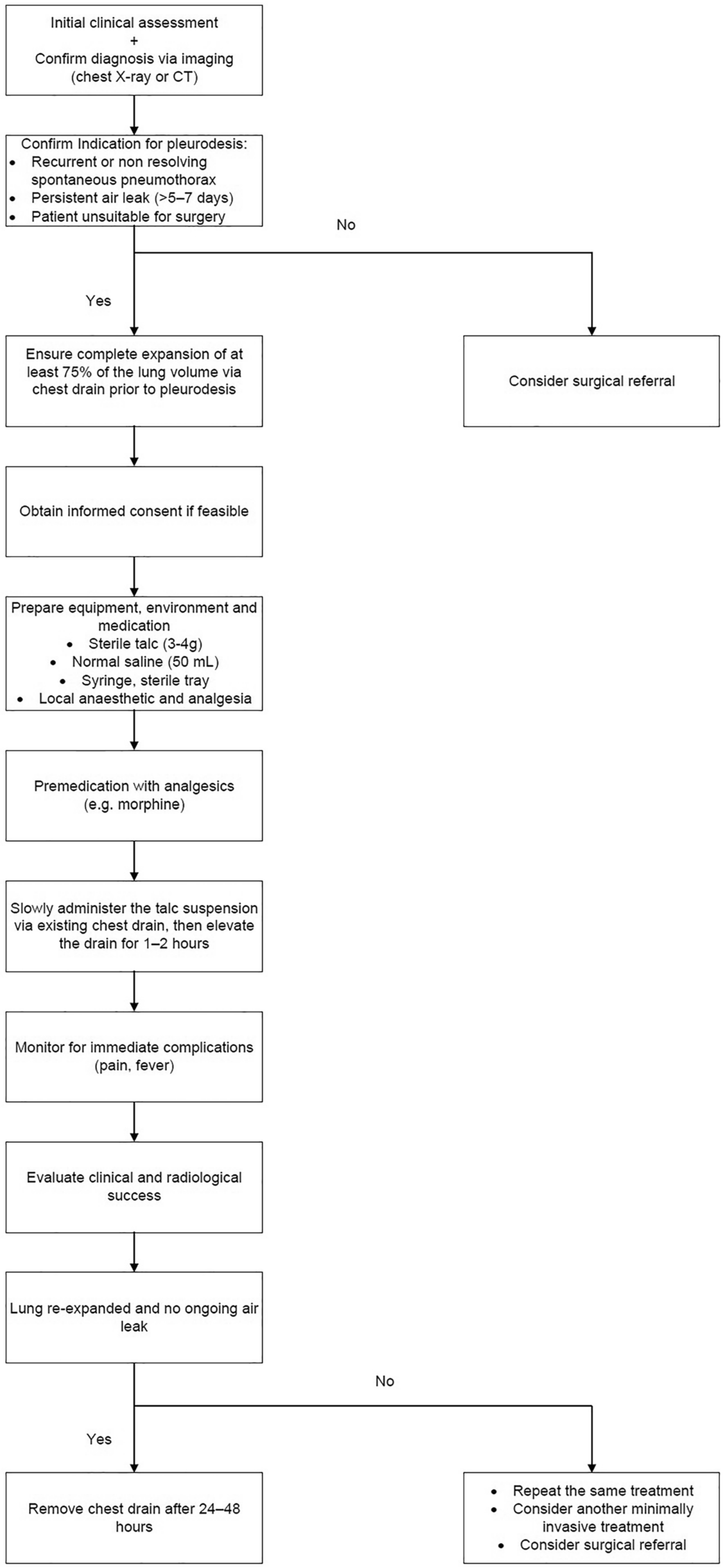


Fig. 4 Procedural flow chart related to talc slurry pleurodesis. *CT* computed tomography

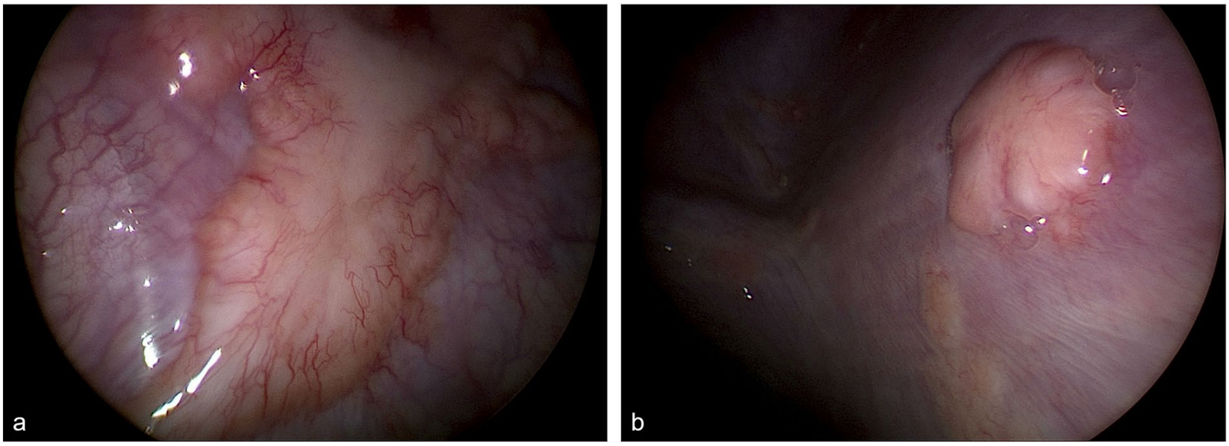


Fig. 5 **a**, **b** Inflammatory pleural plaques (histologically confirmed) as an outcome of previous talc slurry in a patient undergoing medical thoracoscopy for SSP recurrence. *SSP* secondary spontaneous pneumothorax

preferred surgical approach due to its minimally invasive nature, reduced postoperative pain, and shorter recovery time compared to traditional open thoracotomy [48, 71]. Common surgical interventions include the resection of blebs or bullae and pleurodesis, often performed using mechanical abrasion or chemical agents, to obliterate the pleural space and prevent recurrence [72]. In complex cases, pleurectomy may be indicated for definitive management.

The evolution of surgical technique through the use of uniportal access procedures [73, 74] and experimental airway management without the need for intubation [72, 75, 76] is progressively revolutionising this field.

The indication for surgical treatment should be considered according to the patient's individual surgical and anaesthesiologic risk profile to ensure optimal outcomes.

Physical Therapy and Pain Management

Currently, the literature does not clearly define whether specific physiotherapy interventions can be implemented in terms of treatment and rehabilitation of patients affected by pneumothorax. It is important to note that the following physiotherapy interventions, performed with or without specific devices, are contraindicated in the presence of an undrained pneumothorax: mechanical insufflation-exsufflation, positive expiratory pressure, intrapulmonary percussive ventilation, continuous positive airway pressure, and mechanical ventilation [77]. In addition, the use of an incentive spirometer may be difficult to attain as a result of the presence of chest pain [78].

Considering that bed rest leads to the development of atelectasis and that chest pain can further reduce lung volume as a result of antalgic reduced chest expansion, it is reasonable to suggest that pain management (both with pharmacological intervention and physical therapy), early mobilization and recovery of ambulation should be priority goals to promote lung re-expansion [79].

Risk Factor Correction and Post-acute Event Counselling

Addressing pneumothorax risk factors is critical for prevention and recurrence reduction. Smoking represents a significant risk factor [80], and its cessation significantly decreases the likelihood of pneumothorax recurrence, while optimising the prognosis of underlying lung diseases, such as chronic obstructive pulmonary disease. Each patient should avoid these activities for 7 days after full radiological resolution: high-altitude flights or activities related to changes in intrathoracic pressure (e.g. diving,

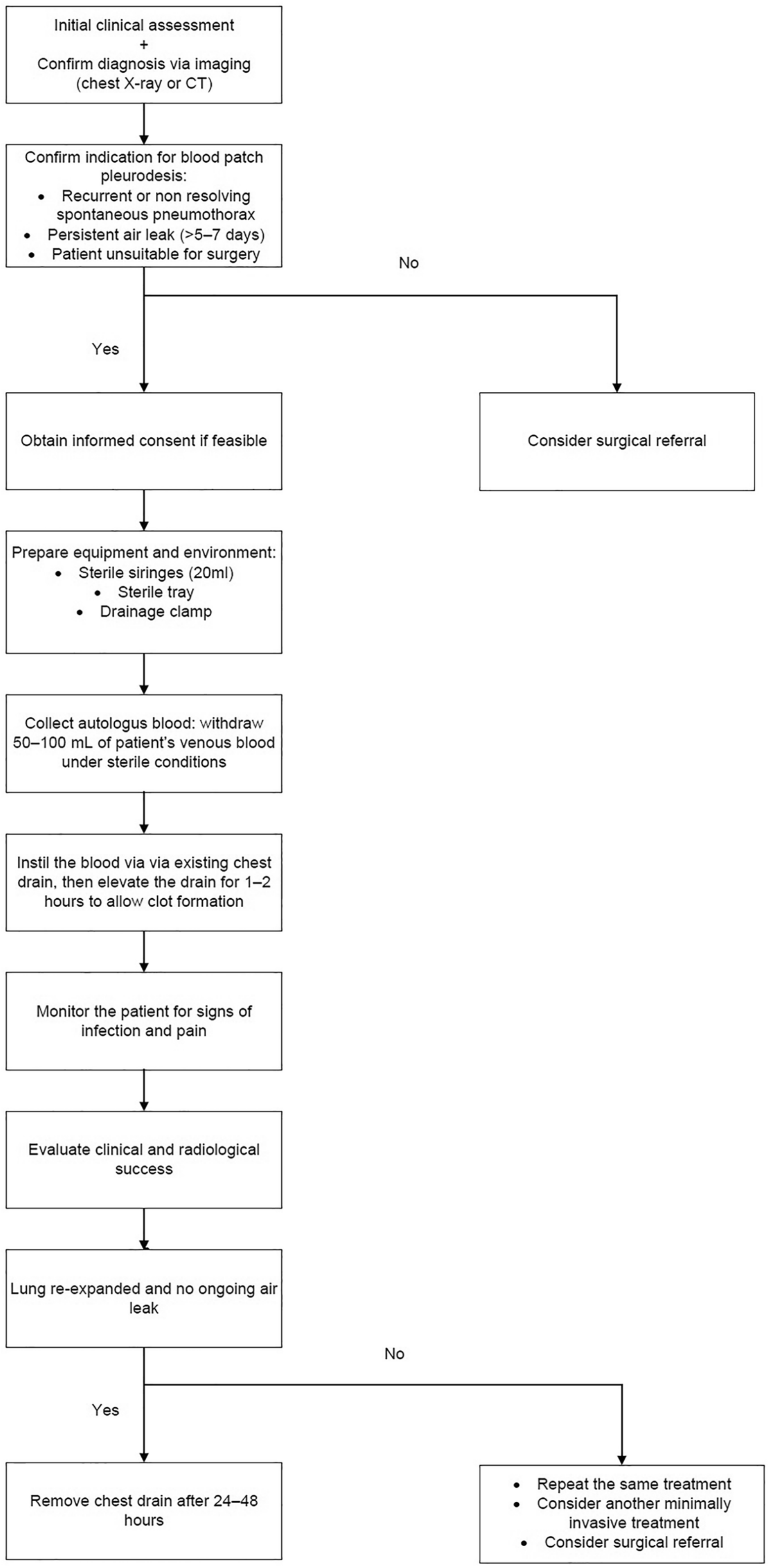
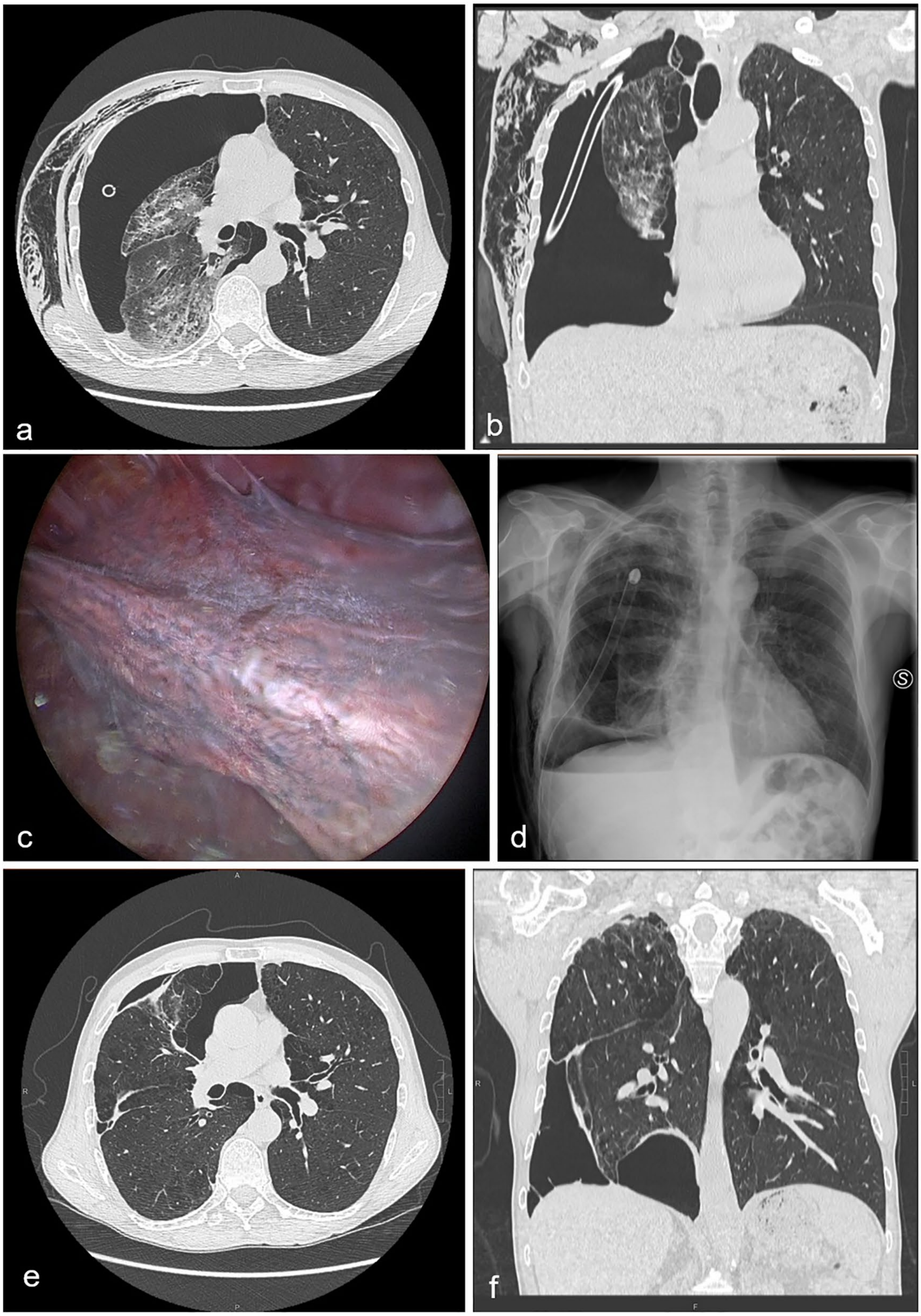


Fig. 6 Procedural flow chart related to autologous blood patch pleurodesis. *CT* computed tomography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◂**Fig. 7** Stages in the management with medical thoracoscopy of an SSP patient with multiple comorbidities and contraindication to surgery. **a** Axial thoracic tomography image showing a right pneumothorax with subcutaneous emphysema and pleural drainage in place. **b** Coronal chest CT image showing the position of the large-calibre drainage. **c** Endoscopic view while performing medical thoracoscopy with talc poudrage demonstrating the presence of long-standing adhesions. **d** Post-thoracoscopic chest X-ray demonstrating partial lung re-expansion. **e**, **f** Axial and coronal post-thoracoscopy chest CT images showing partial pleural apposition, sufficient for the removal of the pleural drainage with a patient in symptomatic control. The patient is then discharged and reassessed with distant radiographic follow-up. *CT* computed tomography

contact sports, heavy exercise or lifting). Scuba diving should be contraindicated unless definitive pneumothorax treatments have been performed [81].

Future Directions

Future directions in pneumothorax therapy will have to focus on protocols for choosing the appropriate minimally invasive techniques, optimising outpatient management and identifying models of predicting recurrence risk. The LISP trial (Longitudinal Investigation of Secondary Pneumothorax) [82] should report this year and give a clearer view into the management practice of SSP. Whilst Brown et al. have shown that in selected cases of PSP, conservative management is feasible [15], there have been some concerns raised about its widespread applicability. As such, there are several trials ongoing. The CONSEPT trial—CONservative versus Standard carE for primary spontaneous PneumoThorax [83]—seeks to determine if conservative management of PSP can be done in a different population with broader inclusion criteria and the Conservative Management in Traumatic Pneumothoraces in the Emergency Department (CoMiTED) [84] seeks to answer the question if conservative management is safe in patients with traumatic pneumothoraces in whom there is equipoise about drain insertion due to relative lack of symptoms or indications. The Pragmatic non-inferiority Randomised trial Investigating Needle aspiration versus ChEst drain for Secondary Spontaneous Pneumothorax (PRINCE-SSP) trial [85] seeks to answer if needle aspiration is safe in SSP as opposed to chest drain insertion, which, as described above, has been the cornerstone of pneumothorax management. A randomised controlled trial, Randomised trial of Suction for Primary Pneumothorax Early Resolution: an examination of clinical effectiveness and cost effectiveness (RASPER trial) [86], is also in progress to determine if thoracic suction is useful in PSP. All the trials mentioned above are currently recruiting in the UK with results expected in the next year or so.

CONCLUSION

A limitation of this manuscript lies in the inherent subjectivity involved in the authors' selection of specific bibliographic references, intended to guide the reader towards management strategies for pneumothorax that are considered to have practical relevance to clinical practice.

The effective management of pneumothorax requires an approach tailored to the aetiology, severity, patient-specific factors and choices. Advances in diagnostic imaging, minimally invasive interventions, and ambulatory care have significantly improved outcomes. Continuous research into innovative therapies and personalized strategies promises to further optimise patient care.

AUTHORSHIP

All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

Author Contributions. Alberto Fantin: conceptualization, writing the original draft, reviewing, project administration. Nadia Castaldo, Simone Salvitti, Ernesto Crisafulli, Giulia Sartori, Filippo Patrucco, Paolo Vailati, Giuseppe Morana, Vincenzo Patruno: writing and editing. Avinash Aujayeb: writing and editing, supervision, project administration.

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Declarations

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Ethical Approval. This article is based on reviews of current guidelines and literature and did not involve any new studies with human participants or animals performed by any of the authors. Written informed consent was obtained from all patients depicted in the clinical cases and respective images.

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