Management options for the complicated pleural space

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Abstract Clinicians frequently encounter patients with malignant and benign diseases involving the pleural space. Complications from these disease processes pose clinical challenges that often require a multi-disciplinary management approach. Here we discuss therapeutic options available for complicated diseases of the pleural space, including loculated malignant effusions, complicated pleural infections, hemothorax, nonexpanding lung, pleural thickening, and persistent bronchopleural fistulas. Our objective is to review current literature on management of these complex issues.

Keywords Malignant pleural effusion · Parapneumonic · Empyema · Hemothorax · Trapped lung · Pleural thickening · Mesothelioma · Bronchopleural fistula

Introduction

Pleural diseases are a commonly encountered clinical problem affecting an estimated 3000 per million people [1]. A wide range of medical problems with both malignant and benign etiology affect the pleural space. Unfortunately, pleural diseases may persist or progress despite standard therapeutic intervention. Here we address complicated pleural conditions which are clinically challenging for physicians and are a source of significant morbidity and mortality for patients. These conditions typically require

careful case-by-case evaluation with a multi-disciplinary management approach.

Loculated malignant effusion

Malignant pleural effusions (MPE) affect more than 150,000 people per year in the United States [2]. Patients with good performance status and projected lifespan may benefit from chemical pleurodesis, with 81–93 % success with talc, 80–85 % with tetracycline or doxycycline, and 70–79 % with bleomycin [2]. However, pleural adhesions and loculations can prohibit uniform distribution of pleurodesis agents thereby preventing successful obliteration of the pleural space. Their presence will affect selection of the ideal intervention for a patient.

Locating adhesions and loculations is an important procedural consideration, for example with placement of chest tubes or thoracoscopy trocars. Computerized tomography (CT) is only moderately sensitive for detecting pleural adhesions. CT of patients undergoing video-assisted thoracoscopic surgery (VATS) was able to correctly identify the presence of adhesions in 71 % of cases, with similar specificity for excluding them (72 %) [3]. However, the ability to identify specific individual adhesions was significantly less, with only 38 % correctly located and 27 % false-positive identifications. Evaluation for lung sliding by transthoracic ultrasonography identified individual adhesions with 80.6–88.0 % sensitivity and 82.6–96.1 % specificity [4, 5]. Identifying the sliding pleural sign, however, may be confounded by concurrent pneumothorax and is more difficult at the apices and for patients with chronic obstructive lung disease [4, 5].

Pleural loculations can limit the distribution of chemical pleurodesis agents introduced via chest tube, thereby reducing therapeutic success. Alternatively, medical thoracoscopy and VATS can be used to provide visual guidance of pleural

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fluid drainage, perform adhesiolysis, thereby restoring a single pleural space, and confirm uniform distribution of pleurodesis agents [2, 6•]. Thoracoscopic intervention can be considered for treating loculated malignant effusions in patients who have good functional status and are otherwise pleurodesis candidates.

For patients who cannot tolerate thoracoscopic procedures, intrapleural administration of fibrinolytics, for example streptokinase and urokinase, can increase pleural fluid drainage and improve dyspnea [7, 8]. Randomized, controlled evaluation of intrapleural streptokinase for MPE revealed lung re-expansion for a greater number of patients (96 % versus 75 %) and increased subsequent success with doxycycline pleurodesis (75 % versus 56 %) [9]. An indwelling pleural catheter can also be inserted with ultrasound guidance into the dominant loculated space for symptom relief.

Complicated pleural infection

Pleural infections are frequently encountered medical problems associated with high mortality ranging from 6–20 % [10, 11••, 12]. Pleural infections typically progress through three stages. The acute or exudative stage is characterized by a free-flowing effusion. During the fibrinopurulent stage, pleural fluid becomes turbid and viscous; adhesions and loculations often develop during this stage. Finally, an organizing fibrous peel can form on the visceral pleura resulting in a trapped lung during the organizing phase. Several classification systems have been developed to describe the complexity of the pleural infection and guide therapeutic algorithms based upon fluid appearance, microbiological, chemical, and radiographic characteristics [13, 14].

For simple, free-flowing parapneumonic effusions, antibiotic therapy and possible drainage with thoracentesis is usually sufficient [14, 15••]. Complicated effusions require tube thoracostomy or more advanced drainage intervention. Chest tube diameter must be sufficient to evacuate infected material from the pleural space. Larger-bore chest tubes have traditionally been used for complicated pleural infections and empyemas because smaller tubes are at higher risk of occlusion by viscous pleural fluid or pus. However, the Multi-center Intrapleural Sepsis Trial (MIST1) did not reveal different clinical outcomes on the basis of chest tube size, including mortality, need for surgical intervention, or length of hospitalization [16]. Smaller chest tubes placed by the Seldinger technique were associated with less pain resulting from either different tube size or method of insertion. Of note, choice of chest tube diameter was at the discretion of the treating physician, so the results may have been biased by patient and fluid characteristics; randomized

data addressing this issue is currently lacking. Placement of smaller-caliber catheters can be performed with real-time ultrasound guidance; this is particularly helpful for patients with loculations [17].

Intrapleural fibrinolytic administration has been used to prevent or treat fibrinous loculations associated with pleural infections, with mixed outcomes. The MIST1 is the largest randomized trial which evaluated the instillation of 250,000 IU streptokinase twice daily for 3 days compared with placebo. There was no significant benefit with regard to mortality, need for surgical intervention, radiography outcome, or hospital length-of-stay [10]. Meta-analysis including previous studies also does not support routine use of intrapleural fibrinolytics for treatment of pleural infections [18]. The subsequent MIST2 trial compared combination tissue plasminogen activator (t-PA) and DNase versus either agent alone versus placebo control. Mean change in radiographic opacity (−29.5 % vs −17.2 %), need for surgical referral (OR 0.17), and hospital length-of-stay (−6.7 days) significantly favored combination t-PA and DNase compared with placebo; monotherapy with either agent was not dissimilar from placebo [11••]. These findings supported the hypothesis that DNase reduces pleural fluid viscosity and improves the efficacy of fibrinolytics by cleaving free deoxyribonucleic acid and other bacterial debris. Current major societal guidelines preceded the MIST2 study and do not advocate routine use of intrapleural fibrinolytics [15••].

Thoracoscopy can also been used in lieu of fibrinolytics to remove adhesions and loculations, suction infected material, and any fibrinous covering of the visceral pleura, thus preventing development of a fibrous peel and trapped lung [19–21]. Decortication success is generally better for less complicated pleural infections. Though still controversial, some authors believe thoracoscopy to be superior to thoracotomy because of reduced procedure-related morbidity, hospital length-of-stay, and complications with equivalent efficacy [22, 23]. However, these studies may be biased by disease complexity and operator skill. Thoracotomy is still of major importance in advanced empyemas [22] and approximately 6 % of thoracoscopic cases require conversion to open thoracotomy or subsequent surgical intervention [24]. The fibrinopurulent phase is generally regarded as the ideal period to instill intrapleural fibrinolytics and perform such intervention as thoracoscopic adhesiolysis and surgical decortication. Aggressive initial therapy including procedural intervention has been demonstrated to be advantageous for highly complicated pleural infections, with reduced need for secondary intervention (43 % versus 11 %) but without mortality difference compared with less aggressive initial therapy [12].

Unresolving empyemas and post-surgical empyemas may require specialized rescue intervention which enables

chronic drainage of the pleural space until the infection resolves. Many of these cases are further complicated by the development of prolonged bronchopleural fistulas (BPF) [25–27]. Open thoracostomy uses a vertical chest incision with rib resection and large bore chest tube insertion, enabling drainage of the pleural space. The tract closes as the chest tube is slowly withdrawn in a process that may take 2 to 3 months. Open-window thoracostomy removes segments of 2 or 3 adjacent ribs to create an opening enabling drainage of the pleural space to the outside environment, although the disruption of the chest wall can be aesthetically undesirable. Variations of the open window thoracostomy include the Eloesser procedure, which uses a skin flap for BPF closure, and vacuum-assisted closure [22]. The Clagett procedure is a staged process with initial open pleural drainage and irrigation with antibiotic solution. Once granulation tissue forms, the pleural cavity is filled with antibiotic solution and then closed [28]. Comparison of these techniques is difficult and the choice of procedure is highly dependent upon the specific situation and the expertise of the surgeon.

Hemothorax

A small amount of blood can make a pleural effusion appear bloody. Pleural fluid hematocrit >50 % of serum hematocrit is therefore used to define a hemothorax. Bleeding into the pleural space most commonly results from trauma or procedure-related injury. Spontaneous hemothorax can occur with rupture of pleural adhesions, malignancy, and as a complication of anticoagulation therapy for pulmonary embolism. Rarer causes include endometriosis, exostoses, rupture of pulmonary vascular malformations in Osler–Weber–Rendu syndrome, and rupture of thoracic artery aneurysms, for example the aorta, internal mammary, or intercostal arteries, which can occur with Ehlers Danlos syndrome and neurofibromatosis [29].

Upright chest radiography is a useful initial tool for evaluation for hemothorax in trauma patients. Chest CT provides greater image resolution and helps identify potential sites of injury. An arterial blush of contrast into the pleural space indicates active bleeding and requires urgent intervention. Measurement of the radiographic Hounsfield units of pleural fluid on CT scan can also help distinguish between hemothorax and chronic pleural effusion. Bedside ultrasonography is rapidly available and has higher sensitivity than chest radiography (92 % versus 62 %) for detecting hemothorax and facilitating time-sensitive evaluation of trauma patients [30].

Chest tube thoracotomy is the usual initial intervention for traumatic hemothorax to remove blood and prevent the development of infection or trapped lung. Larger-bore chest tubes are less likely to become obstructed, although prospective analysis did not demonstrate significant difference in outcomes between 28 F to 32 F tubes compared with larger 36 F to 40 F tubes; there was no difference in volume of blood drained, tube duration, or complications including pneumonia, empyema, or retained hemothorax [31]. Prophylactic use of first-generation cephalosporins was advocated by the Eastern Association for Trauma guidelines for reducing infectious sequelae associated with hemothoraces requiring chest tube placement [32]. Unfortunately, data available at that time were limited to nine small studies, many of which were retrospective or unblinded. Subsequent prospective, randomized, double-blind comparison of intravenous cefazolin for the duration of tube thoracostomy versus 24 hours of cefazolin therapy versus placebo for 224 patients did not reveal significant reduction in empyema or pneumonia in either antibiotic group compared with placebo [33]. Nevertheless, data support prophylactic antibiotic use to reduce infections in the broader population of patients with chest drains for blunt and penetrating thoracic trauma [34]. Prophylactic antibiotics are, therefore, a reasonable consideration for traumatic hemothoraces but are not warranted in most spontaneous cases.

Surgical intervention with VATS or thoracotomy may be required to investigate the pleural space, control bleeding, repair damaged visceral and vascular structures, or evacuate the hemothorax. In a prospective evaluation of 328 patients with hemothorax, 30.8 % of patients could be managed by observation alone. Estimated retained hemothorax volume <300 mL was the strongest independent predictor of success of this management strategy [35]. For patients requiring procedural intervention, VATS was the initial procedure for 33.5 %. However, 26.5 % required two procedures, 5.4 % required three procedures, and 20.4 % ultimately required thoracotomy to fully evacuate the pleural space or treat subsequent empyema [36].

Pneumonia has been shown to develop in 19.5 % and empyema in 26.8 % of patients with retained hemothorax [35]. Intervention for retained hemothorax is highly dependent upon the clinical situation given the associated procedural risk relative to the potential development of hemothorax-related complications. For retained hemothorax, surgical investigation is the preferred initial therapy over placement of additional chest tube drains. A small randomized trial demonstrated shorter drainage duration (2.53 versus 4.50 days), reduced post-procedure hospital length-of-stay (3.60 versus 7.21 days), reduced total hospital length-of-stay (5.40 versus 8.13 days), and reduced hospital-related costs ($7,689 versus $13,273) with VATS compared with placement of additional tube thoracotomy [37]. Use of VATS versus thoracotomy is dependent upon the clinical situation and the skill of the surgeon.
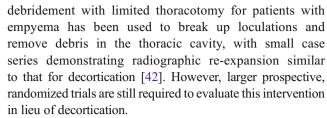
Nonexpanding lung

A number of acute and chronic etiologies can mechanically prevent full lung expansion and apposition of the visceral and parietal pleura. Inflammation from acute infectious and non-infectious processes may result in development of a fibrinous visceral pleural peel preventing lung expansion. Parapneumonic infections are the most common infectious etiology, but spontaneous bacterial pleuritis associated with hepatic hydrothorax is also a potential cause. Non-infectious etiologies include hemothorax, cardiothoracic surgery, and such underlying medical conditions as uremia or rheumatoid pleuritis. Malignancy directly involving the visceral pleura can prevent lung expansion. Less frequently, endobronchial obstruction and subsequent lung collapse may cause para-malignant effusions.

Patients with trapped lung will commonly develop pleural effusions, but dyspnea may not be significantly improved by large-volume drainage. Patients may have increased cough or pain with fluid removal, with rapid re-accumulation of the effusion. In addition, lung elastance may be increased after fluid drainage resulting in the generation of abnormally negative intrathoracic pressures and development of a pneumothorax or hydropneumothorax [38]. In the era of ultrasound-guided thoracentesis, post-procedural pneumothorax is much more likely to result from trapped lung than procedure-related complications [38]. Pleural effusions secondary to trapped lung will tend to recur and drainage is warranted only if the patient is symptomatic [19].

As previously discussed, complicated pleural infections can result in the development of a fibrinous coating on the lung preventing expansion. Lung entrapment from pleural infections may subside after antibiotic therapy. However, once a fibrinous peel organizes into a fibrinous membrane, spontaneous resolution is unlikely and surgical decortication is required to restore lung expansion [19]. Surgical removal of the constricting membrane can be performed by VATS but may require conversion to muscle-sparing thoracotomy. Decortication for patients with empyema can improve lung function but does not completely correct the impairment. Postoperative improvements in forced expiratory volume in one second (FEV_1) range from 17.5–19.2 % of predicted values, and increases in vital capacity (VC) range from 16.6–18.5 % of predicted values. Lung perfusion and radiographic expansion are also increased after surgical decortication [39, 40]. Similarly, decortication for trapped lung after coronary artery bypass grafting results in improvements of FEV_1 by 15.0±6.3 % and VC by 17.6±6.4 % of predicted values [41]. and However, surgical decortication has a mortality risk of 1.3–6.6 % [20].

Less aggressive alternatives to surgical decortication have been investigated to resolve trapped lung. Surgical debridement with limited thoracotomy for patients with empyema has been used to break up loculations and remove debris in the thoracic cavity, with small case series demonstrating radiographic re-expansion similar to that for decortication [42]. However, larger prospective, randomized trials are still required to evaluate this intervention in lieu of decortication.

Malignancy is a frequent cause of pleural effusions and approximately 5–20 % may become complicated by trapped lung [43]. Rapid recurrence of pleural fluid associated with trapped lung makes intermittent thoracentesis drainage problematic. Pleurodesis is not an option, because it requires apposition of the visceral and parietal pleura. One study showed 100 % failure of pleurodesis for MPE with trapped lung or with an elastance greater than 19 cm H_2O [44]. Furthermore, treatment options for patients with MPE are often limited by their poor functional status associated with advanced malignancy. Palliative surgical decortication is not recommended for this patient population because it requires prolonged hospitalization, and morbidity and mortality are high [45, 46].

Indwelling pleural catheters have been shown to provide symptom relief for 48–94 % of patients with MPE with trapped lung [47–49]. Despite the trapped lung, indwelling pleural catheters induced spontaneous pleurodesis in 48 % of patients after a mean of 94 days [49]. Complications such as air leak, catheter occlusion, cellulitis, and development of loculations may occur in up to 15 % of patients [49]. In addition, indwelling pleural catheters provide minimally invasive palliation for patients with late-stage malignancies. Minimizing procedure-related risks and hospitalization time for these patients is of paramount importance. Pleuroperitoneal shunts have also been used for recurrent drainage of pleural fluid but are limited by high morbidity, shunt failure, translocation of malignant cells into the peritoneal cavity, and lower patient compliance [46]. Intrapleural fibrinolysis with urokinase may improve radiographic lung re-expansion of loculated MPE with trapped lung, but further study of this palliative intervention is required [50].

Endobronchial malignancies causing airway obstruction may result in a pleural effusion associated with post-obstruction atelectasis. Unlike other malignancy-associated pleural effusions, these effusions are characteristically transudates and malignant cells are not present. Relief of the endobronchial obstruction is required for lung re-expansion and requires bronchoscopic intervention [6•, 51].

Pleural thickening

Pleural abnormalities may be focal or diffuse and are associated with both benign and malignant diseases. Isolated

pleural plaques are the most common benign form of pleural thickening and may be associated with asbestos exposure, trauma, hemothorax, or tuberculosis. The presence of multiple plaques, however, typically results from asbestos exposure [52]. Asbestos fibers are theorized to be directly transported to the pleural surface after inhalation, or to be transported along lymphatics. Asbestos fibers induce pleural inflammation and collagen deposition within the parietal pleura. Asbestos-related pleural plaques are well-circumscribed, often bilateral but asymmetric, and are commonly adjacent to ribs along the posterior chest wall and central tendons of the diaphragm. Although they are a marker of asbestos exposure, there is a latency period of at least 20 years before development [53, 54]. Calcifications within plaques are commonly seen on chest radiography and are related to time duration since exposure. Plain chest radiography is often sufficient for longitudinal evaluation of pleural plaques, though chest CT enables more sensitive evaluation of detailed characteristics, for example calcifications [55, 56]. Pleural plaques are sometimes associated with parenchymal fibrosis seen in asbestosis, but the two entities may exist independently of each other [57]. Patients with pleural plaques are at greater risk of asbestosis and should be monitored for such [52, 58, 59]. Although pleural plaques are benign, their presence is an indicator of risk of mesothelioma development [52], possibly associated with greater burden of asbestos exposure or retention [60, 61].

Diffuse pleural thickening usually involves the visceral pleura, including the costophrenic angle with fibrosis extending into adjacent lung parenchyma. Adjacent parietal pleura may also become involved, with development of adhesions complicating the pleural space. Unlike the well-circumscribed fibrosis of parietal pleural plaques, diffuse pleural thickening may be heterogeneous in appearance, both in thickness and in demarcation of borders. Both entities, however, may occur simultaneously [62]. Diffuse pleural thickening is associated with asbestos exposure but can develop in response to other causes of pleuritis, for example infection, tuberculosis, trauma, radiation, pulmonary embolism, and benign asbestos-related pleural effusion [63, 64]. Unlike pleural plaques, diffuse pleural thickening may result in significant restrictive impairment [64].

Rounded atelectasis is a unique form of benign asbestos-related pleural thickening that presents with a round radiographic pleural opacity and characteristic "comet sign" tail extending towards the hilum [65]. Patients are usually asymptomatic and their lesions discovered incidentally [66].

Malignant pleural thickening is most commonly secondary to metastatic disease. The clinical course of patients with pleural metastases is often complicated by recurrent malignant effusion, loculations, and nonexpanding lung. Mesothelioma is a primary pleural tumor that deserves separate discussion given its unique disease characteristics and associated therapeutic challenges. Pathologic diagnosis is often difficult with only pleural fluid analysis or limited pleural biopsy from closed needle biopsy. As a result, medical thoracoscopy or VATS is recommended for diagnostic evaluation [67•].

Mesotheliomas have poor overall prognosis and patient survival has not benefited significantly from medical therapy. Surgical intervention for mesothelioma includes pleurectomy with decortication and more extensive extrapleural pleurectomy (EPP) involving resection of the visceral and parietal pleura, pericardium, and diaphragm. The Mesothelioma and Radical Surgery (MARS) study, the only randomized, controlled evaluation, demonstrated reduced median survival of 14.4 months with EPP compared with 19.5 months without EPP [68••]. Coupled with high procedure-associated morbidity (~50 %) and mortality (4–15 %) [69], EPP is generally discouraged [67•]. In contrast, pleurectomy with decortication palliates such symptoms as dyspnea, chest discomfort, and recurrent pleural effusions with significantly less operative risk than EPP [70].

Alternative methods of symptom control include medical thoracoscopy with talc poudrage or insertion of an indwelling pleural catheter [2, 71]. Mesotheliomas are notorious for seeding the tracts of pleural procedures. An early randomized trial demonstrated a significant decrease in tumor seeding if prophylactic radiotherapy was applied to intervention sites [72]. Subsequent studies, however, found no benefits [73, 74].

Persistent bronchopleural fistula

BPF most commonly result of thoracic trauma or post-surgical complications. Development of a BPF is a particularly deleterious complication of surgical lung resection with occurrence ranging from 0.5–0.7 % for lobectomy and 7.1–10.2 % for pneumonectomy [25–27]. BPF is more common after right compared with left-sided pneumonectomy (13.2–17.4 % versus 5.0 %) [26, 27]. Other risk factors include use of staple closure and preoperative neoadjuvant or postoperative adjuvant chemotherapy [26]. Predisposing factors for spontaneous development of pneumothorax include underlying bullae or cysts, pulmonary infection, malignancy, necrosis from radiation or chemotherapy, acute respiratory distress syndrome, and disease states resulting in elevated intrathoracic pressure, for example exacerbation of obstructive lung disease and Boerhaave syndrome [29, 75].

Initial intervention includes careful monitoring with repeat radiographic imaging, high-flow supplemental oxygen, evacuation of air by needle aspiration, and placement of a chest tube. Smaller-bore chest tubes can be used, because the risk of occlusion is substantially less than for drainage of
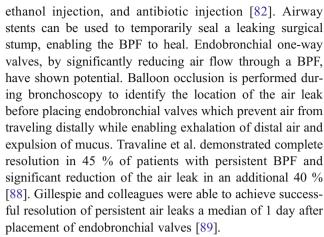
a viscous pleural effusion or empyema. However, air leaks can be more than 16 L min^{-1} and tube size should enable sufficient drainage to match the rate of air leak through the BPF [76–78]. The Fanning equation describes turbulent flow of moist gas through a tube ($v=\pi^2 r^5 P/fl$, where v is flow, r is radius, P is pressure, f is the Fanning friction factor, and l is length) [76, 79, 80]. Flow is directly proportional to tube radius to the 5th power and illustrates why a larger-bore tube may be necessary for brisk air leaks or if the initial tube size is insufficient to evacuate the pneumothorax.

Mechanical ventilation may be required for respiratory failure associated with pneumothorax. Persistent air leakage delays BPF healing and can cause loss of tidal volume, loss of positive end expiratory pressure (PEEP), and false ventilator cycling. In turn, this may worsen ventilation–perfusion matching, hypoxemia, and respiratory compensation of acidosis [81, 82]. Ventilator strategies utilizing reduced tidal volumes, PEEP, and inspiratory times are used to limit air flow through a BPF and promote healing [81–84]. Additional alternative methods of ventilation have also been tried including selective intubation of the healthy lung, double lumen intubation with independent ventilation, high-frequency oscillatory ventilation, high-frequency jet ventilation, and extracorporeal support methods [81, 82, 85, 86]. Differential lung ventilation with either selective mainstem bronchial intubation or double lumen intubation reduces or eliminates air flow to the lung with the BPF but requires the unaffected lung to be healthy enough to support ventilation and oxygenation. High-frequency modes of ventilation are able to oxygenate the patient with lower mean airway pressures, thereby reducing the volume of air leaking through the BPF. Although these methods of ventilation have theoretical advantages, objective data are lacking.

Conservative measures have variable success, with reports of 4–45 % of patients requiring more aggressive surgical or endoscopic intervention [25, 87]. CT scans can be useful to help locate the BPF site before intervention [87]. Surgical closure of BPF is successful in 80–100 % of cases [29, 82]. It is recommended that patients be evaluated for surgical or alternative means of therapy if their BPF fails to resolve after 5 days [82]. A wide range of surgical closure techniques have been developed, including chronic open drainage, stump closure reinforced with intercostal muscle, an omental flap, trans-sternal bronchial closure, and thoracoplasty with or without extrathoracic chest wall muscle transposition [22, 82]. Staged closure after chronic open drainage, for example with an Eloesser or Clagett procedure, can also be used. However, patients must be able to tolerate VATS or open thoracotomy.

Bronchoscopic intervention performed to occlude persistent BPF includes instillation of fibrin glue, albumin-glutaraldehyde tissue adhesive, cellulose, gel foam, poly(-ethylene glycol), cyanoacrylate glue, or topical silver nitrate,

ethanol injection, and antibiotic injection [82]. Airway stents can be used to temporarily seal a leaking surgical stump, enabling the BPF to heal. Endobronchial one-way valves, by significantly reducing air flow through a BPF, have shown potential. Balloon occlusion is performed during bronchoscopy to identify the location of the air leak before placing endobronchial valves which prevent air from traveling distally while enabling exhalation of distal air and expulsion of mucus. Travaline et al. demonstrated complete resolution in 45 % of patients with persistent BPF and significant reduction of the air leak in an additional 40 % [88]. Gillespie and colleagues were able to achieve successful resolution of persistent air leaks a median of 1 day after placement of endobronchial valves [89].

Finally, the American College of Chest Physicians recommends pleurodesis for secondary prevention of recurrent spontaneous pneumothorax after the first occurrence [29]. If bullae are present, concurrent bullectomy can prevent future occurrence of spontaneous pneumothorax. Surgical bullectomy with talc poudrage is recommended over other options, for example talc slurry instillation through a chest tube.

Conclusions

Pleural diseases are a frequently encountered clinical problem. Complicated pleural conditions cause significant morbidity and mortality and usually have no standardized treatment algorithms. Additional studies are necessary to develop better interventions for these patients.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. Du Rand I, Maskell N. Introduction and methods: British thoracic society pleural disease guideline 2010. Thorax. 2010;65:ii1–3.
2. Hsia D, Musani AI. Management of malignant pleural effusions. Curr Respir Care Rep. 2012;1(2):73–81.
3. Mason AC, Miller BH, Krasna MJ, et al. Accuracy of CT for the detection of pleural adhesions. Correlation with video-assisted thoracoscopic surgery. Chest. 1999;115:423–7.

4. Cassanelli N, Caroli G, Dolci G, et al. Accuracy of transthoracic ultrasound for the detection of pleural adhesions. Eur J Cardiothorac Surg. 2012;45:813–8.

5. Wei B, Wang T, Jiang F, et al. Use of transthoracic ultrasound to predict pleural adhesions: a prospective blinded study. Thorac Cardiovasc Surg. 2012;60:101–4.

6. • Hsia D, Musani AI. Interventional pulmonology procedures for the diagnosis and therapeutic management of lung cancer. Minerva Pneumol. 2012;51:27–43. *Review of endobronchial and pleural intervention for lung cancer available to the interventional pulmonologist.*

7. Davies CW, Traill ZC, Gleeson FV, et al. Intrapleural streptokinase in the management of malignant multiloculated pleural effusions. Chest. 1999;115:729–33.

8. Hsu LH, Soong TC, Feng AC, et al. Intrapleural urokinase for the treatment of loculated malignant pleural effusions and trapped lungs in medically inoperable cancer patients. J Thorac Oncol. 2006;1:460–7.

9. Okur E, Baysungur V, Tezel C, et al. Streptokinase for malignant pleural effusions: a randomized controlled study. Asian Cardiovasc Thorac Ann. 2011;19:238–43.

10. Maskell NA, Davies CW, Nunn AJ, et al. U.K. controlled trial of intrapleural streptokinase for pleural infection. N Engl J Med. 2005;352:865–74.

11. •• Rahman NM, Maskell NA, West A, et al. Intrapleural use of tissue plasminogen activator and DNase in pleural infection. N Engl J Med. 2011;365:518–26. *Trial evaluating the potential role of t-PA and DNase in the treatment of complicated pleural infections.*

12. Cheng G, Vintch JR. A retrospective analysis of the management of parapneumonic empyemas in a County teaching facility from 1992 to 2004. Chest. 2005;128:3284–90.

13. Light RW. A new classification of parapneumonic effusions and empyema. Chest. 1995;108:299–301.

14. Colice GL, Curtis A, Deslauriers J, et al. Medical and surgical treatment of parapneumonic effusions. An evidence-based guideline. Chest. 2000;18:1158–71.

15. •• Davies HE, Davies RJ, Davies CW, et al. Management of pleural infection in adults: British thoracic society pleural disease guideline 2010. Thorax. 2010;65 Suppl 2:ii41–53. *Recent large societal guidelines on the management of pleural infections.*

16. Rahman NM, Maskell NA, Davies CW, et al. The relationship between chest tube size and clinical outcome in pleural infection. Chest. 2010;137:536–43.

17. Liu YH, Lin YC, Liang SJ, et al. Ultrasound-guided pigtail catheters for drainage of various pleural diseases. Am J Emerg Med. 2010;28:915–21.

18. Tokuda Y, Matsushima D, Stein GH, et al. Intrapleural fibrinolytic agents for empyema and complicated parapneumonic effusions: a meta-analysis. Chest. 2006;129:783–90.

19. Doelken P. Clinical implications of unexpandable lung due to pleural disease. Am J Med Sci. 2008;335:21–5.

20. Molnar TF. Current surgical treatment of thoracic empyema in adults. Eur J Cardiothorac Surg. 2007;32:422–30.

21. Tassi GF, Davis RJ, Noppen M. Advanced techniques in medical thoracoscopy. Eur Respir J. 2006;28:1051–9.

22. Zahid I, Nagendran M, Routledge T, et al. Comparison of video-assisted thoracoscopic surgery and open surgery in the management of primary empyema. Curr Opin Pulm Med. 2011;17:255–9.

23. Tong BC, Hanna J, Toloza EM, et al. Outcomes of video-assisted thoracoscopic decortications. Ann Thorac Surg. 2010;89:220–5.

24. Brutsche MH, Tassi GF, Gyorik S, et al. Treatment of sonographically stratified multiloculated thoracic empyema by medical thoracoscopy. Chest. 2005;128:3303–9.

25. Naranjo Gomez JM, Carbajo Carbajo M, Valdivia Concha D, et al. Conservative treatment of post-lobectomy bronchopleural fistula. Interact Cardiovasc Thorac Surg. 2012;15:152–4.

26. Ucvet A, Gursoy S, Sirzai S, et al. Bronchial closure methods and risks for bronchopleural fistula in pulmonary resections: how a surgeon may choose the optimum method? Interact Cardiovasc Thorac Surg. 2011;12:558–5562.

27. Darling GE, Abdurahman A, Yi QL, et al. Risk of right pneumonectomy: role of bronchopleural fistula. Ann Thorac Surg. 2005;79:433–77.

28. Thourani VH, Lancaster RT, Mansour KA, et al. Twenty-six years of experience with the modified eloesser flap. Ann Thorac Surg. 2003;76:401–5.

29. Baumann MH, Strange C, Heffner JE, et al. Management of spontaneous pneumothorax: an American College of Chest Physicians Delphi consensus statement. Chest. 2001;119:590–602.

30. Brooks A, Davies B, Smethhurst M, et al. Emergency ultrasound in the acute assessment of haemothorax. Emerg Med J. 2004;21:44–6.

31. Inaba K, Lustenberger T, Recinos G, et al. Does size matter? a prospective analysis of 28–32 versus 36–40 French chest tube size in trauma. J Trauma. 2012;72:422–7.

32. Luchette FA, Barrie PS, Oswanski MF, et al. Practice management guidelines for prophylactic antibiotic use in tube thoracostomy for traumatic hemopneumothorax: the EAST Practice Management Guidelines Work Group. J Trauma. 2000;48:753–7.

33. Maxwell RA, Campbell DJ, Fabian TC, et al. Use of presumptive antibiotics following tube thoracostomy for traumatic hemopneumothorax in the prevention of empyema and pneumonia – a multi-center trial. J Trauma. 2004;57:742–8.

34. Bosman A, de Jong MB, Debeij J, et al. Systematic review and meta-analysis of antibiotic prophylaxis to prevent infections from chest drains in blunt and penetrating thoracic injuries. Br J Surg. 2012;99:506–13.

35. Dubose J, Inaba K, Okoye O, et al. Development of posttraumatic empyema in patients with retained hemothorax: Results of a prospective observational AAST study. *J Trauma* 73:752–757.

36. DuBose J, Inaba K, Demetriades D, et al. Management of post-traumatic retained hemothorax: a prospective, observational, multicenter AAST study. J Trauma. 2012;72:11–24.

37. Meyer DM, Jessen ME, Wait MA, et al. Early evacuation of traumatic retained hemothoraces using thoracoscopy: a prospective, randomized trial. Ann Thorac Surg. 1997;64:1396–400.

38. Heidecker J, Huggins JT, Sahn SA, et al. Pathophysiology of pneumothorax following ultrasound-guided thoracentesis. Chest. 2006;130:1173–84.

39. Rzyman W, Skokowski J, Romanowicz G, et al. Decortication in chronic pleural empyema – effect on lung function. Eur J Cardiothorac Surg. 2002;21:502–7.

40. Gokce M, Okur E, Baysungur V, et al. Lung decortication for chronic empyaema: effects on pulmonary function and thoracic asymmetry in the late period. Eur J Cardiothorac Surg. 2009;36:754–8.

41. Celik S, Celik M, Aydemir B, et al. Long-term results of lung decortications in patients with trapped lung secondary to coronary artery bypass grafting. Ann Thorac Cardiovasc Surg. 2012;18:109–14.

42. Kho P, Karunanantham J, Leung M, et al. Debridement alone without decortications can achieve lung re-expansion in patients with empyema: an observational study. Interact Cardiovasc Thorac Surg. 2011;12:724–7.

43. Milanez RC, Vargas FS, Filomeno LB, et al. Intrapleural talc for the treatment of malignant pleural effusions secondary to breast cancer. Cancer. 1995;75:2688–92.

44. Lan RS, Lo SK, Chuang ML, et al. Elastance of the pleural space: a predictor for the outcome of pleurodesis in patients with malignant pleural effusion. Ann Intern Med. 1997;126:768–74.

45. Bernard A, de Dompsure RB, Hagry O, et al. Early and late mortality after pleurodesis for malignant pleural effusion. Ann Thorac Surg. 2002;74:213–7.

46. Schulze M, Boehle AS, Kurdow R, et al. Effective treatment of malignant pleural effusion by minimal invasive thoracic surgery: thoracoscopic talc pleurodesis and pleuroperitoneal shunts in 101 patients. Ann Thorac Surg. 2001;71:1809–12.

47. Pien GW, Gant MJ, Washam CL, et al. Use of an implantable pleural catheter for trapped lung syndrome in patients with malignant pleural effusion. Chest. 2001;119:1641–6.

48. Efthymiou CA, Masudi T, Thorpe JA, et al. Malignant pleural effusion in the presence of trapped lung. Five-year experience of PleurX tunneled catheters. Interact Cardiovasc Thorac Surg. 2009;9:961–4.

49. Qureshi RA, Collinson SL, Powell RJ, et al. Management of malignant pleural effusion associated with trapped lung syndrome. Asian Cardiovasc Thorac Ann. 2008;16:120–3.

50. Hsu LH, Soong TC, Feng AC, et al. Intrapleural urokinase for the treatment of loculated malignant pleural effusions and trapped lungs in medically inoperable cancer patients. J Thorac Oncol. 2006;5:460–7.

51. Hsia D, Musani AI. Interventional pulmonology. Med Clin N Am. 2011;95:1095–114.

52. American Thoracic Society. "Diagnosis and initial management of nonmalignant diseases related to asbestos. Am J Respir Crit Care Med. 2004;170:691–715.

53. Larson TC, Meyer CA, Kapil V, et al. Workers with Libby amphibole exposure; retrospective identification and progression of radiographic changes. Radiology. 2010;255:924–33.

54. Epler GR, McLoud TC, Gaensler EA. Prevalence and incidence of benign asbestos pleural effusion in a working population. JAMA. 1982;247:617–22.

55. Muller NL. Imaging of the pleura. Radiology. 1993;186:297–309.

56. Aberle DR, Balmes JR. Computed tomography of asbestos-related pulmonary parenchymal and pleural diseases. Clin Chest Med. 1991;12:115–31.

57. Sison RF, Hruban RH, Moore GW, et al. Pulmonary disease associated with pleural "asbestos" plaques. Chest. 1989;95:831–5.

58. Rogan WJ, Gladen BC, Ragan NB, et al. US prevalence of occupational pleural thickening: a look at x-rays from the First National Health and Nutrition Examination Survey. Am J Epidemiol. 1987;126:893–900.

59. Hillerdal G. Non-malignant asbestos pleural disease. Thorax. 1981;36:669–75.

60. Hillerdal G, Henderson DW. Asbestos, asbestosis, pleural plaques and lung cancer. Scand J Work Environ Health. 1997;23:93–103.

61. Hillerdal G. Pleural plaques and the risk for bronchial carcinoma and mesothelioma. Chest. 1994;105:144–50.

62. Miller A, Miller JA. Diffuse pleural thickening superimposed on circumscribed pleural thickening related to asbestos exposure. Am J Ind Med. 1993;23:859–71.

63. Lilis R, Lerman Y, Selikoff IJ. Symptomatic benign pleural effusions among asbestos insulation workers: residual radiographic abnormalities. Br J Ind Med. 1988;45:443–9.

64. Schwartz DA, Fuortes LJ, Galvin JR, et al. Asbestos-induced pleural fibrosis and impaired lung function. Am Rev Respir Dis. 1990;141:321–6.

65. Batra P, Brown K, Hayashi K, et al. Rounded atelectasis. J Thorac Imaging. 1996;11:187–97.

66. Cugell DW, Kamp DW. Asbestos and the pleura. Chest. 2004;125:1103–17.

67. • Scherpereel A, Astoul P, Baas P, et al. Guidelines of the European Respiratory Society and the European Society of Thoracic Surgeons for the management of malignant pleural mesothelioma. Eur Respir J. 2010;35:479–95. *Recent large societal guidelines on the management of mesothelioma.*

68. •• Treasure T, Lang-Lazdunski L, Waller D, et al. Extra-pleural pneumonectomy versus no extra-pleural pneumonetomy for patients with malignant pleural mesothelioma: clinical outcomes of the Mesothelioma and Radical Surgery (MARS) randomised feasibility study. Lancet. 2011;12:763–72. *Randomized evaluation of EPP for mesothelioma.*

69. Zellos L, Jaklitsch MT, Al-Mourgi MA, et al. Complications of extrapleural pneumonectomy. Semin Thorac Cardiovasc Surg. 2007;19:355–9.

70. Soysal O, Karaoglanoglu N, Demiracan S, et al. Pleurectomy/decortications for palliation in malignant pleural mesothelioma: results of surgery. Eur J Cardiothorac Surg. 1997;11:210–3.

71. Aelony Y, Yao JF. Prolonged survival alter talc poudrage for malignant pleural mesothelioma: case series. Respirology. 2005;10:649–55.

72. Boutin C, Rey F, Viallat JR. Prevention of malignant seeding after invasive diagnostic procedures in patients with pleural mesothelioma. A randomized trial of local radiotherapy. Chest. 1995;108:754–8.

73. O'Rourke N, Garcia JC, Paul J, et al. A randomised controlled trial of intervention site radiotherapy in malignant pleural mesothelioma. Radiother Oncol. 2007;84:18–22.

74. Bydder S, Phillips M, Joseph DJ, et al. A randomised trial of single-dose radiotherapy to prevent procedure tract metastasis by malignant mesothelioma. Br J Cancer. 2004;91:9–10.

75. Williams NS, Lewis CT. Bronchopleural fistula: a review of 86 cases. Br J Surg. 1976;63:520–2.

76. Batchelder TL, Morris KA. Critical factors in determining adequate pleural drainage in both the operated and nonoperated chest. Am Surg. 1962;28:296–302.

77. Powner DJ, Cline D, Rodman GH. Effect of chest-tube suction on gas flow through a bronchopleural fistula. Crit Care Med. 1985;13:99–101.

78. Rusch VW, Capps JS, Tyler ML, et al. The performance of four pleural drainage systems in an animal model of bronchopleural fistula. Chest. 1988;93:859–63.

79. Baumann MH. What size chest tube? What drainage system is ideal? And other chest tube management questions. Curr Opin Pulm Med. 2003;9:276–81.

80. Miller KS, Sahn SA. Chest tubes. Indications, technique, management and complications. Chest. 1987;91:258–64.

81. Maung AA, Kaplan LJ. Mechanical ventilation after injury. J Intensive Care Med. 2012 Sep 6. [epub ahead of print]

82. Lois M, Noppen M. Bronchopleural fistulas. An overview of the problem with special focus on endoscopic management. Chest. 2005;128:3955–65.

83. Downs JB, Chapman RL. Treatment of bronchopleural fistulas during continuous positive pressure ventilation. Chest. 1976;69:363–6.

84. Zimmerman JE, Colgan DL, Mills M. Management of bronchopleural fistula complicating therapy with positive end expiratory pressure (PEEP). Chest. 1973;64:526–9.

85. Feely TW, Keating D, Nishimura T. Independent lung ventilation using high-frequency ventilation in the management of a bronchopleural fistula. Anesthesiology. 1988;69:420–2.

86. Ha DV, Johnson D. High frequency oscillatory ventilation in the management of a high output bronchopleural fistula: a case report. Can J Anaesth. 2004;51:78–83.

87. Ricci ZJ, Haramati LB, Rosenbaum AT, et al. Role of computed tomography in guiding the management of peripheral bronchopleural fistula. J Thorac Imaging. 2002;17:214–8.

88. Travaline JM, McKenna RJ, De Giacomo T, et al. Treatment of persistent pulmonary air leaks using endobronchial valves. Chest. 2009;136:355–60.

89. Gillespie CT, Sterman DH, Cerfolio RJ, et al. Endobronchial valve treatment for prolonged air leaks of the lung: a case series. Ann Thorac Surg. 2011;91:270–3.