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Postpneumonectomy empyema: risk factors, prevention, diagnosis, and management

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Abstract

Postpneumonectomy empyema is a collection of pus in the pleural space after removal of the underlying lung. Postpneumonectomy empyema is a serious complication responsible for high rates of morbidity and mortality. Several risk factors for the development of postpneumonectomy empyema have been highlighted in the literature. The association of postpneumonectomy empyema with a bronchopleural fistula increases the rate of mortality by flooding the remaining lung. The management of postpneumonectomy empyema depends on the timing of presentation and the presence or absence of a bronchopleural fistula. The goals of care in the acute period are mainly preservation of the contralateral lung and sterilization of the pleural space, which may take a considerable time. The aims in the late period are closure of the bronchopleural fistula, obliteration of the pleural space, and closure of the chest wall.

Keywords

Bronchial fistula, empyema, pleural, pleural diseases, pneumonectomy, respiratory tract fistula

Introduction

Historically, the first pneumonectomy for benign disease was performed in 1931, and two years later, it was performed for cancer.[1] Since then, postpneumonectomy empyema (PPE) has been a major concern for thoracic surgeons. PPE is defined as the presence of frankly purulent fluid in the pleural space after pneumonectomy, or a positive microbiological study even if the pleural fluid is not purulent. It is a challenging complication, occurring at a rate of 2%–16%.[2,3] The presence of an associated bronchopleural fistula (BPF) must be systematically determined because it affects the prognosis and steps of management. The rate of mortality is significant, ranging from 25% to 71% in the case of associated BPF, due to spillage into the remaining lung.[4,5] Several risk factors have been implicated in this complication.[2,6] The management depends mainly on the time of presentation of PPE and the presence or absence of BPF. In the early stage of PPE, the goals are to protect the remaining lung in the case of BPF, and to sterilize the pleural space. Thereafter, the goals are obliteration of the pleural space and closure of the chest wall.

Risk factors and prevention

Several significant risk factors for the occurrence of BPF and PPE have been determined.[7] Pneumonectomy performed on the right sided is well established as a risk factor for developing a BPF.[8] This is because the left bronchial stump is protected under the aortic arch and vascularized by the mediastinal tissue. Also, the right side is most commonly supplied by one bronchial artery, while the left side is frequently supplied by two bronchial arteries.[8] According to Hollaus and colleagues,[9] the diameter of the bronchial stump is a risk factor for BPF when it exceeds 25 mm. Mechanical ventilation favors the development of BPF, due to continual

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pressure on the bronchial stump.[2,10] Chronic smoking and chronic obstructive pulmonary disease contribute to the occurrence of BPF by their proven deleterious effects on the healing process.[11,12] Surgical reinterventions, including completion pneumonectomy, significantly increase the incidence of BPF due to difficulties in dissecting the pulmonary hilum, leading to devascularization of the bronchial stump.[13] Challenging hilar dissection is also associated with benign diseases, especially chronic lesions such as bronchiectasis and destroyed lung.[14] Mechanical bronchial closure is regarded by some authors to constitute a risk factor for the development of BPF; therefore, manual bronchial suturing, particularly with overlocking sutures, has been recommend.[15,16] Martin and colleagues[17] found that induction therapy increases the risk of BPF. Diabetes, malnutrition, and various immunosuppressive therapies (steroids, antimetabolites) have all been implicated in the development of BPF by increasing the risk of infection and dehiscence of the bronchial stump.[18]

Prevention is based on avoiding BPF and infection of the pleural cavity in the postoperative period. Patients must stop smoking and receive respiratory physiotherapy. Patients who will benefit from a pneumonectomy for infectious diseases must be well prepared in the preoperative period by antibiotic prophylaxis and correct respiratory physiotherapy. Also, patients with destroyed lung related to underlying empyema are usually malnourished, and high-protein hypercaloric nutrition is indicated, ensuring effective thoracic drainage in the case of pyothorax. During surgery, opening of lesions in the pleural space must be avoided. A reduced rate of BPF can be obtained by avoiding devascularization of the bronchial stump and protecting it with a muscle flap. To avoid high pressure on the bronchial stump by mechanical ventilation, extubation in the immediate postoperative phase is preferable, if not, intubation with a double-lumen endotracheal tube is mandatory.

Diagnosis

PPE can occur a few days to several years after pneumonectomy. The clinical presentation depends mainly on the presence or absence of a BPF, which occurs more frequently during the first 3 weeks after a pneumonectomy. Essential respiratory signs are dyspnea, chest pain, and coughing. Sputum with a serosanguinous appearance is evidence of a fistula. Flooding of the remaining lung due to a BPF can cause life-threatening respiratory distress.[18] Asthenia and anorexia are especially marked in cases of early PPE. Physical examination is focused on infection of the chest wall or a cutaneous fistula in the case of late PPE. Laboratory tests look for an increase in white blood cell count and persistent elevation of C-reactive protein or a secondary rise exceeding 100 $mg{\cdot}L^{-1}$, which is highly sensitive (100%) and specific (91.4%).[19] Chest radiography and thoracic computed tomography (Figure 1) usually shows a residual pleural cavity filled with air in the early stage of PPE, followed by a fluid level that gradually rises until a white hemithorax is obtained. A fall in this fluid level indicates the presence of a BPF. Therefore, Robert and colleagues[20] described "benign emptying of the postpneumonectomy space", which is a rare situation wherein patients are clinically well, without a BPF on bronchoscopy, but with a sudden drop in the pleural fluid level. Thoracic imaging can also reveal cutaneous emphysema, pneumomediastinum, and multiple air-fluid levels, indicating thoracocentesis or drainage of the pleural space.

The mode of definitive diagnosis of BPF remains bronchoscopy. However, the sensitivity of this method is low for small fistulas. In this case, instillation of physiological serum onto the bronchial stump can be beneficial by showing an air leakage. Thoracocentesis can be undertaken for diagnostic or therapeutic purposes, by allowing evacuation of the pleural space, especially in cases of acute dyspnea. The technique must adhere strictly to aseptic rules to avoid the risk of contamination of the pneumonectomy cavity. Due to the mediastinal shift and diaphragmatic elevation, it is preferable to puncture outside the medioclavicular line in front of the 2nd or 3rd intercostal space or on the anterior axillary line after local anesthesia. The macroscopic appearance is either frankly purulent or of a serosanguinous appearance in most cases. A cytological study looks for altered polynuclear neutrophil counts, defining empyema, and a bacteriological study aims at identification of organisms including mycobacterium tuberculosis.

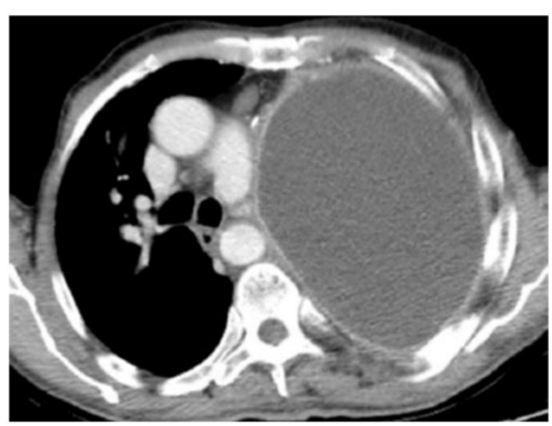

Figure 1. Thoracic axial computed tomography showing a left postpneumonectomy empyema.

Etiological forms and complications

PPE are generally classified into three types: PPE associated with a BPF, PPE without a BPF, and PPE of hematogenous origin. The most frequent and deadly type is PPE with BPF, with which the aforementioned risk factors are associated. PPE usually occurs within 2 to 3 weeks, and bronchoscopy can confirm the presence of a BPF. Because of the risk of flooding the remaining lung, chest drainage of the pleural space must be performed urgently. PPE without a BPF is usually secondary to intraoperative contamination, such as in surgery for an infected underlying lung (bronchiectasis, destroyed lung, complex aspergilloma) by opening of lesions in the pleural space.[21] PPE of hematogenous origin is secondary to contamination following bacteriemia (such as from a dental abscess), and the condition is sustained for two reasons: absence of a BPF, and the nature of the bacteria identified, which are not the usual agents of nosocomial infection. In the acute phase, the most dreaded complication is spillage of secretions into the remaining lung, which is responsible for respiratory distress that can be life-threatening. Also, if the infection is severe, septic shock is possible if there is no early management, especially in the setting of immunosuppression. In the chronic phase, empyema is not very evident in terms of clinical signs, and the empyema will become fistulized into adjacent organs, especially cutaneous tissue.

Management

The management of PPE is directed by several factors, especially the time between pneumonectomy and PPE, presence or absence of PBF, size of PBF, and clinical status of the patient.[22] The goal in the acute phase is to obtain a local control of infection and protection of the remaining lung (Table 1). Management in the late phase aims to achieve sterilization of the pleural space, closure of the BPF, obliteration of the pleural space, and chest wall closure (Table 1). Three weeks is the period used by some authors to distinguish the acute phase from the chronic phase.[23]

Antibiotics

In humans, data on the diffusion of antibiotics into the pleural cavity for post-surgical empyema are lacking. Two options are available for PPE: systematic antibiotics, and intrapleural antibiotic irrigation. Theoretically, diffusion of antibiotics along the pneumonectomy cavity is impeded by damage to the microcirculation in the pleural space, due to the presence of parietal pleura alone, without visceral pleura.[24] Despite that, Stern and colleagues[25] showed that there was no difference in diffusion of antibiotics between a pneumonectomy and lobectomy cavity. Additionally, penetration of amoxicillin and vancomycin into the pleural space in post-surgical empyema is good, with pleural concentrations higher than plasma concentrations in the majority of cases.[25] Intrapleural antibiotics are not recommended by the British Thoracic Society.[26] Antibiotics should be tailored based on the results of culture and a sensitivity profile. If not, antibiotics should cover both common community-acquired bacterial pathogens and anaerobic organisms. If these antibiotics are administrated by intravenous injection, they can be changed to oral therapy when clinical and biochemical improvements are seen.[26] Antibiotic prophylaxis is strongly indicated in the setting of infectious or inflammatory disease.[2]

Table 1. Management of postpneumonectomy empyema.

Aim	Acute phase	Late phase
Control of infection	Antibiotic products Chest tube drainage VATS debridement Irrigation lavage Thoracotomy debridement Bronchopleural fistula closure: endoscopic, transpleural, or transpericardial	Open window thoracostomy Bronchopleural fistula closure Vacuum-assisted closure
Pleural cavity obliteration		Thoracoplasty Muscle transposition Omentoplasty

VATS: video-assisted thoracoscopic surgery.

Chest tube thoracostomy and serial irrigation

When a diagnosis of PPE is obtained, drainage of the pleural space must be performed in order to control local infection and stop contralateral spillage in the case of an associated BPF.[27] The chest tube must be placed outside the medioclavicular line or on the anterior axillary line at the 2nd or 3rd intercostal space because of anatomical modifications after pneumonectomy. Pleural drainage prepares the patient for subsequent surgical treatment under better general and respiratory conditions. It should be noted that chest tube drainage in the early phase of PPE can be enhanced with a suction system, but at a gentle pressure because of the high risk of mediastinal shifting. In late PPE, this risk is not sustained, and suction can be applied at higher pressures. Some authors have purposed cyclical irrigation of the pleural space with antimicrobial or antiseptic solutions, and have demonstrated that this technique is effective and convenient. In addition, it causes minimal patient discomfort and shortens the duration of hospital stay.[28] On the other hand, some authors consider that cyclical irrigation does not allow removing debris and false membranes that can cause recurrence of the empyema, especially in cases of late PPE.[29] Serial irrigation can be performed through the chest tube or after debridement of the cavity by video-assisted thoracoscopic surgery (VATS) or thoracotomy.[30]

Debridement of the pleural space

Debridement of the pleural space can be performed by VATS, a repeat thoracotomy (same approach as the initial pneumonectomy), or another thoracotomy. It is preferable to perform these interventions using a double-lumen endotracheal tube and a selective intubation probe to protect the contralateral lung. The aim is to remove large debris and false membranes from the space, which may cause a recurrence of empyema.

Debridement by VATS

In 1997, Wait and colleagues[31] reported a randomized trial comparing chest tube pleural drainage plus streptokinase and VATS in empyema thoracis. They demonstrated that there were considerably fewer recurrences in the VATS group, and that chest drainage and hospital stay were also substantially reduced.[31] However, this less invasive approach (VATS) has rarely been proposed in the management of PPE without BPF or with a minor BPF.[29] One of the reasons may be the fear of using VATS for a serious and potentially lethal complication.[32] This technique allows removal of most of the false membranes and debris and washing the pleural space under direct visual control.[32] VATS is indicated in the setting of acute PPE where the fibrinous material can be safely removed. A double-lumen endotracheal tube is used to ventilate the remaining lung and bypass a fistula if present. First, chest tube drainage of the pleural space and bronchoscopic evaluation of BPF are performed. Bronchoscopic sealing with a sclerosing agent in BPF < 3 mm has been recommended. On the other hand, fistulas > 3 mm require an open surgical procedure, and VATS is not advised. Some authors have undertaken VATS debridement after failure of serial irrigation, and others continue cyclical irrigation after a VATS procedure.[33]

Debridement by thoracotomy

Thoracotomy can be indicated immediately for debridement of the pleural space or after failure of a VATS approach. The choice of a new thoracotomy or a redo of the old thoracotomy depends on the acute or chronic status of PPE. In the acute phase, debridement through the old thoracotomy is useful, because retraction of the pneumonectomy cavity is not crucial. Some authors prefer an anterolateral thoracotomy because of mediastinal shifting and elevation of the diaphragm. Selective intubation is preferable to protect the remaining lung in case of an associated BPF. After debridement, closure of the BPF is performed. The aim is to preserve the muscles of the chest wall for subsequent obliteration of the pleural space.

Open window thoracostomy

Open window thoracostomy (OWT) is the most invasive pleural drainage procedure. The first open pleural drainage performed for empyema was described by Samuel Robinson[34] in 1916, and subsequently revised by Eloesser[35] in 1935 for tuberculous empyema. OWT is usually reserved for PPE with BPF (especially > 8 mm) after stabilization of the patient's clinical condition, and it is also recommended in cases of PPE without a fistula if other therapeutic options have failed. The appropriate choice of the site and number of resected ribs can promote rapid closing of the fistula as well as the pleural space. The technique consists of resection of 2 to 3 ribs by 8–10 cm at the level of the axillary region (second or third rib), above the previous thoracotomy (or another site), preserving the muscles of the chest wall. This procedure is finished by suturing the cutaneous layers in the areas of pachypleuritis. The choice of this level is to account for the postpneumonectomy diaphragm elevation and mediastinal shift. This resection will allow sufficient access to the pleural space for effective packing, serial dressing changes, and debridement, until we have a sterile cavity (Figure 2). The timing for closure of the OWT varies from 3 weeks to approximately 1 year.[22] Some authors have advocated multiple negative cultures before closure of the

Figure 2. Open window thoracostomy in a patient who presented with postpneumonectomy empyema and benefited initially from a pneumonectomy for left destroyed lung.

OWT, whereas others require a visually clean pleural cavity with healthy granulation tissue.[22,36]

Closure of a bronchopleural fistula

BPF is present in as many as 80% of patients with PPE, and this clinical presentation adds considerable mortality to an already dangerous situation.[22] BPF is mainly managed according to its size and localization.[37] Only 30% of postpneumonectomy fistulas resolve with conservative management.[38] Endoscopic treatment can be performed in cases with a high risk of mortality if a surgical procedure is undertaken. Endoscopic techniques are especially indicated for small fistulas (<6 mm), and several products have been tried, including mucosal injection of polidocanol, injection of fibrin (Tissucol), and biological glues (BioGlue). In a large and proximal fistula, the preferred endoscopic treatment is an endobronchial stent, even though the rate of success is low.[39] It should be noted that all published series concerning endoscopic treatment are retrospective studies or isolated cases, and the level of evidence remains low.[37]

When endoscopic treatment has failed, or in the case of a large BPF, an invasive surgical procedure for closure is mandatory. This can be carried out by a transpleural or transsternal approach. The transpleural approach involves closure of the BPF via an open window thoracostomy or thoracotomy, or injection of glue when VATS is performed for PPE with a minor BPF.[22] Significant inflammation or fibrotic tissue may obscure tissue planes, making isolation of the bronchial stump challenging, especially in late PPE.[22] The bronchial stump can be stapled or manually sutured, and buttressed with a healthy and well-vascularized tissue such as extrathoracic muscles, diaphragm, or an omentum flap.[22] A transsternal approach was described in 1961 by Abruzzini and colleagues.[40] This approach can be performed initially in the case of a left bronchial stump buried in the mediastinum, or after failure of a transpleural approach. The advantage is dissection through healthy planes free of inflammation and adhesions, allowing effective isolation of the airway. Also, healthy and vascularized tissues (pericardium or thymic tissue) for buttressing the bronchial stump are readily available.[22]

Vacuum-assisted closure

Vacuum-assisted closure (VAC) consists of a special wound drape with a tube connected to an electric pump that applies continuous or intermittent controlled subatmospheric pressure to the wound.[41] Fleischman and colleagues[42] were the first to publish a study on VAC in 1993. VAC is currently widely used for wound closure in virtually all areas of the body. Varker and colleagues[43] were the first group to describe successful management of post-resectional empyema by VAC in 2006. The advantages of this technique are increased blood flow due to continuous negative aspiration, acceleration of granulation tissue formation, and reduction of the wound site.[44] In the acute period of PPE, it is recommended to apply negative pressure of −50 to −75 mm Hg to avoid ipsilateral mediastinal shift. However, in the late phase, values of negative pressure can achieve −100 to −130 mm Hg because the mediastinum has already stabilized.[45] It should be kept in mind that VAC should be applied for PPE after closure of the BPF because of the effect of negative pressure on the bronchial stump.

Obliteration of the pleural space and closure of the chest wall

Clagett procedure

After the pleural space is judged clean, and granulation tissue has appeared, filling of this space is the next step. Claggett's technique was described in 1963 and consists of closure of the OWT by direct approximation of different layers, and filling the space with antibiotic solution.[46] This technique is simple and less aggressive, but it poses a significant risk of recurrence, leading several teams to prefer filling with muscle transposition even in the case of a cavity of small size. Pairolero and colleagues[47] first modified the Clagett technique in 1990, demonstrating the role of intrathoracic muscle transposition. The operative mortality of this technique is less than 10% and the overall success rate exceeds 80%.[48] The most frequent muscles used for obliteration are latissimus dorsi, serratus anterior, pectoralis major. The choice of these muscles for transposition should be based on the previous surgical procedure and the potential damage.

Thoracoplasty

Thoracoplasty is a historical procedure initially intended for tuberculosis and its complications. The use of this technique in the management of PPE was revived by Gregoire and colleagues[49] in 1987. The goal is to obliterate the pleural space by resection of multiple ribs, either the first 11 ribs, defined as total thoracoplasty, or 5 to 9 ribs defined as partial thoracoplasty. Traditional thoracoplasty consisted of removal of only the posterior portions of ribs, while extended thoracoplasty also excises the anterior portions of the ribs. Several varieties of the techniques have been described, including intrapleural thoracoplasty, as first reported by Schede[50] (removing ribs, periosteum, intercostals muscles, and intercostal bundles through an intrapleural plane), and extrapleural thoracoplasty highlighted by Alexander[51] (preserving the parietal pleura in addition to the periosteum of the ribs and intercostals muscles). Another method of thoracoplasty was described by Andrews in 1960. It consisted of opening a pleuromusculoperiosteal flap created by extrapleural rib resection, debriding the parietal pleura, and suturing the flap directly to the mediastinum.[53] The disadvantages of these different thoracoplasties include progressive scoliosis, chronic pain, progressive pulmonary insufficiency, and a mutilated cosmetic appearance. According to different series of thoracoplasty, the mortality ranges from 0 to 15%, and the success rate varies from 84% to 100%.[53]

Muscle and omentum plasties

Muscle plasty (myoplasty) or epiploplasty is necessary for closure of the pleural space and the OWT. Several muscles can be used for thoracomyoplasty: latissimus dorsi, anterior serratus, and pectoralis major. For this reason, during a thoracotomy for pneumonectomy, these muscles should be preserved. In our department, we perform a posterolateral thoracotomy with muscle sparing in all patients.[54] This technique can also be used in cases of chronic and calcified empyema, whether or not associated with decortication, when pulmonary resection remains impossible.[55] In the study of Massera and colleagues,[56] 12 patients benefited from myoplasty for filling the OWT. The success rate was of 83%, with the death of one patient due to recurrence of empyema. Generally, excess muscle is used for filling because after dissection of the muscle, its volume is decreased. The inconvenient of use of multiple muscular flaps leads to major shoulder sequelae such as scapula alta or a decrease in scapulohumeral articular movements.[56] An omental flap has been described for filling the pleural space or OWT, given its ability to control multidrug-resistant infections, but the drawback is the morbidity of a supplemental laparotomy.[57]

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