Should I Blame the Surgeon: Surgical Complications and Surgical Treatment of the Complications

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7.1 Introduction

In this chapter, authors try to clarify the postoperative major complications seen after thoracic surgery, mainly after lung resections, mediastinal mass resections, and lung transplantations. However this chapter did not deal with postoperative arrhythmias and pulmonary edema, since they were discussed in other chapters in this book.

7.2 Postoperative Hemorrhage and Residual Hemothorax

Chest tubes placed at the end of the operation help to prevent pneumothorax and monitor air leaks and bleeding in early postoperative period. The incidence of postoperative hemorrhage after thoracic surgery is variable and depends on the type of operation: it can occur in 4 % of the cases after pulmonary resections and just 0.33 % after mediastinoscopy [1, 2]. Most of the surgical bleedings (no disorders of coagulation factors – normal INR (international normalized ratio), prothrombin time, and thrombocyte count) are small in amount and generally resolve spontaneously. Just a very few percent of bleeding (up to 2.6 %) needs emergency surgery [3]. Criteria for

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postoperative bleeding control are the amount of drainage and the hemodynamic effects of the drainage. A continuing thoracic hemorrhagic drainage of more than 1000 ml or 200 ml/h for 4–6 h or a sudden drainage of 400 ml may be a sign for a need of an emergency intervention [4, 5]. A blood count should be obtained to detect any changes in the hemoglobin and hematocrit levels, and a chest X-ray should be taken to exclude hemothorax. Hematocrit of the blood obtained from chest tube may indicate the severity of the drainage. If the hematocrit level of the chest drain blood is more than 50 % of the blood hematocrit level, this may be a sign of continuing hemorrhage. During early postoperative course, the thoracic drainage system should be checked – it should be left open (except drainage after pneumonectomy) and should work normal (we have to see oscillation in the drainage tube). Following pneumonectomy, chest tube is recommended to keep clamped and declamped for a few minutes in every hour to control the bleeding. In an intubated patient, with a high positive end-expiratory pressure, the presence of an air leak may be considered as normal. Also, a drain without any oscillation may be normal in such patients.

Recently, due to increase of the patients with coronary artery stents, lung resection candidates are more complicated because of perioperative anticoagulation and antiplatelet therapy (APT). Bertolaccini et al. [6] found that there were no statistically significant differences between the outcomes for the 38 patients receiving APT compared with the controls, in terms of the operative time, the hospital stay, the estimated blood loss, or the morbidity when stratified by the procedure [6]. On the other hand, in Foroulis's study [7], it was shown that APT use was a predisposing factor for postoperative bleeding.

In our experience, with increasing use of video-assisted surgery (VATS) and vascular staplers, massive bleeding due to slipping of ligature is extremely uncommon.

Residual hemothorax, which is not associated with an active bleeding, may occur after thoracic surgery. Up to 15 % of the lung transplant recipients may have this complication. Although thrombolytics may be recommended for a successful treatment, authors prefer VATS for the evacuation of the retained hemothorax [8]. In some patients, changing the location of the chest tube may help in resolving of the residual hemothorax (Fig. 7.1).

7.3 Cardiac Herniation and Tamponade

Cardiac herniation and tamponade are rare complications which may occur after extended pulmonary resections – pneumonectomy or lobectomy – for malignant diseases or pleuropneumonectomy for malignant mesothelioma or thymoma surgery or when pericardiotomy or pericardiectomy is performed in addition to any type of thoracic surgery. It may also occur after lung transplantation [9–11]. Cardiac herniation has a high mortality rate. Thirty to 50 % of cases may be fatal because of a delay either in the diagnosis or the treatment. It is 100 % fatal, if undetected [12].

The incidence of cardiac herniation after pulmonary resections for lung cancer is about 1.7 % [13]. Cardiac herniation after right-sided pneumonectomy is more frequent. It generally occurs in the first 3 postoperative days [14, 15]. It presents with

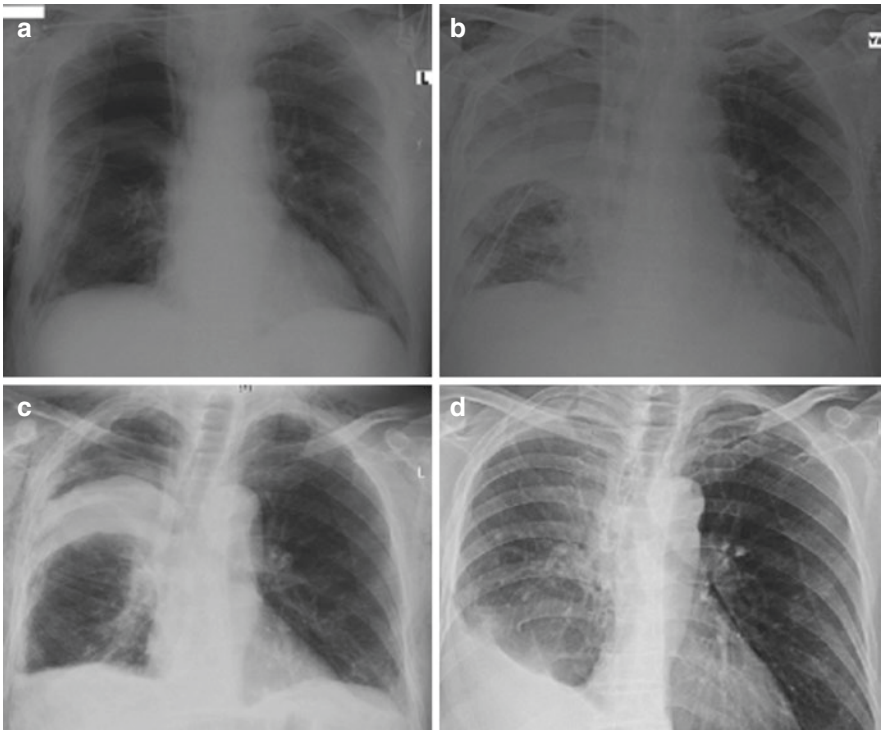

Fig. 7.1 VATS for the evacuation of the retained hemothorax or revising the location of chest tube may help in resolving of the residual hemothorax. (**a**) Early postoperative period. (**b**) Right sided hemothorax, several hours later. (**c**) Residual hemothorax prior to indicated VATS evacuation. (**d**) One week after the VATS with the upper displacement of the residual lung tissue

acute symptoms; there is a critical moment for cardiac herniation and/or tamponade after pneumonectomy. It may occur even in the operation room when patient is turned from the lateral decubitus to the supine position. Acutely significant hypotension may present. The cause of this could be cardiac strangulation (the size of the pericardial graft may be small), cardiac herniation (after pericardiectomy without the closure of the pericardium or patch dehiscence), or tamponade. Transesophageal echocardiography can assist in decision-making before leaving the operating room without reopening the thoracotomy [9]. During the early postoperative period, risk factors for a cardiac herniation could be increased due to the increased intrathoracic pressure with cough and sputum expectoration, the positive-pressure ventilation, the negative suction from drain, and the changes in patient's position (e.g., lying on the side of surgery) [5]. Symptoms start suddenly with the presentation of superior vena cava syndrome, low cardiac output, dysrhythmias, hypotension, cardiac arrest, and shock. For diagnosis, chest X-ray (shadows of the heart and apex), electrocardiography (ECG), and echocardiogram have to be performed for the diagnosis. The clues of the herniation include axis change on ECG, cardiac malrotation on echocardiogram, and hemodynamic collapse [16]. Thorax computed tomography

(CT) (if hemodynamics of patient allows) is also recommended. Treatment should be started immediately – the patient should lie opposite to the surgical side and emergency reoperation has to be performed.

Cardiac tamponade as a complication after extrapleural pneumonectomy may occur in 3.6% of the patients [9]. Postoperative bleeding into the pericardial sac may occur even after lobectomy without pericardiectomy. The patient may have acute clinical presentation and needs an urgent surgery [17]. It was proposed that an intrapericardial retraction of the suture line of the divided pulmonary vein could cause a bleeding from the malfunctioning staple line, and this could lead to a cardiac tamponade [18–20]. It can be treated just with a transcutaneous pericardial drainage and/or immediate surgery.

Cardiac tamponade is characterized by a low cardiac output and a classical Beck's triad (hypotension, muffled heart sounds, and distended neck veins). The chest X-ray, ECG, and echocardiogram should be performed. Surgical treatment is recommended in most of the cases.

These complications might be the cause of cardiac arrest and could have fatal results. Sugarbaker [9] wrote that a cardiac arrest within 10 days postoperatively needs emergency thoracotomy (sometimes in the intensive care unit), open cardiac massage, and pericardial patch removal. Closed cardiac massage is not effective enough after pneumonectomy, since the heart has shifted out of the midline, and it cannot be properly compressed by the sternum and vertebral column. All the members of the postoperative care team must be educated on this point to avoid losing valuable time performing futile closed-chest compressions [9].

7.4 Lobar torsion and gangrene

Lobar, segmental or common basal pyramid torsion is a rare complication which may occur after different type of pulmonary resections and lung transplantation with an incidence rate less than 0.1% [21–23]. Usually torsion occurs in the middle lobe or in the left lower lobe following upper lobe resections. Lobar torsion may develop in the first postoperative 2 weeks [21, 23, 24]. The rotation of the bronchovascular pedicle results with bronchial obstruction and vascular compromise is the cause of gangrene and potential mortality if left untreated [25]. Recognition of pulmonary torsion may be difficult. Clinical presentations vary from slight hypoxemia to septic shock. The clinical findings depend on the degree of rotation in the lobar hilum, generally the rotation is 180 degrees although 90 and 360 degree torsions have been reported [26]. Symptoms of pulmonary torsion can start suddenly with an unexplained dyspnea, productive cough, hemoptysis, tachycardia, and fever, diminished breathing sounds on the effected side or presence of air leak. Chest radiographs may show opacification of the lobe. Findings do not change after nasotracheal aspiration. Chest X ray may demonstrate pneumothorax or collapsed lobe in an unusual position. High resolution chest computed tomography with pulmonary angiogram may confirm the diagnosis - opacification, complete obstruction – "cut-off"- of the bronchus, stenosis or obstruction of kinking vessels are the radiological findings [23]. Flexible bronchoscopy should be performed and

diagnosis may be confirmed if "fish mouth" like appearance is noticed. The transesophageal echocardiography may reveal a presence of potential lethal thrombus in pulmonary vein. Urgent reoperation is indicated, reposition and fixation with following anticoagulant therapy to or complete resection could be performed, if pulmonary infarction or gangrene is suspected. Good analgesia, aggressive antibiotics treatment and mini-tracheostomy to aid suctioning of the secretions may help to reduce the infectious complications after torsion [25].

7.5 Air Leak and Subcutaneous Emphysema

An air leak after pulmonary resection is the most commonly seen finding. In the early postoperative period, it may be seen at a rate of 28–60 % of the patients; however, in the immediate postoperative period, an air leak should not be considered as a pathological condition. A pathological "air leak" may refer to any leakage of the air from the lung identified by noting bubbles in a chest drainage system, by progressive subcutaneous emphysema, or by expanding pneumothorax [27, 28]. On the morning of the postoperative day (POD) 1, an air leak is present in 26–48 % of the patients, with a decreasing incidence toward the POD 4 to as low as 8 % [29–31]. But, in some specific procedures such as bilateral lung volume reduction surgery, an air leak may occur in 90 % of the patients [32]. If an air leak is longer than 7 days (some consider more than 4 days and more than 10 days), it may be considered as prolonged air leak (PAL) [27]. The incidence of PAL is between 9.6 and 15 %, and also it was suggested that PAL may increase the rate of other pulmonary complications, including atelectasis, pneumonia, and empyema, but it is not associated with an increased incidence of cardiopulmonary morbidity [31, 34]. As a result of PAL, the postoperative length of stay is increased [28, 35]. An empyema can develop in 11 % of the patients with PAL [31]. Among the most important risk factors of PAL are an underlying COPD, an inhaled steroid treatment, an active pulmonary infection, insulin-dependent diabetes, a low body mass index (<25.5 kg/m^2), a reduced forced expiratory volume in the first second (FEV1) or reduced predicted postoperative FEV1, an upper lung field resection, lung volume reduction surgery, and intraoperative pleural adhesions [32, 36]. As previously mentioned, chest tube drainage systems may help to monitor the air leak after pulmonary surgery. Different chest tube modalities can be used in postoperative period – water seal or negative pressure drainage system −20 cm H_2O or −10 cm H_2O suction. Chest tubes placed on water seal after pulmonary lobectomy are generally well tolerated and safe; however, they do not reduce the duration of the air leak or the incidence of prolonged air leak when compared with negative suction tubes [33]. Air leak volume can be seen easily, if digital drainage system is used. If a high volume of air leak persists, a pneumothorax and/or subcutaneous emphysema may develop, and negative pressure drainage system should be used in this situation. Chest tube can be removed, if there is no air leak and drainage is less than 200 ml in the last 24 h, but generally drainage volume depends on the underlying disease and the surgery performed. For instance, in our practice we remove chest tube, when there is no drainage and air leak after radical

pleurectomy and decortication surgery for mesothelioma. We may remove chest tubes when the daily drainage is around 400 ml or the drainage is less than 50 ml in the past 12 h in conventional lung resections like a lobectomy.

If there is a small air leak and the lungs are totally expanded, the chest tube may be clamped (which is named as "provocative clamping"), and a chest X-ray should be taken to determine whether the lung remains expanded or not. The tube can be removed if the lung remains expanded, but if the lung collapses and subcutaneous emphysema develops, then the clamp should be opened and the patient can be discharged with a Heimlich valve connected to chest tube. Operation for PAL is rarely necessary. Sometimes talc pleurodesis or an autologous blood patch via chest tube can be tried, or an endobronchial valve may effectively solve this problem especially in high-risk patients [29, 37, 38].

Subcutaneous emphysema (SE) as a complication of air leak may occur when air enters into the subcutaneous space of the chest wall and the soft tissues of the face, neck, upper chest, and shoulder and may change voice. SE could expand to the abdomen subcutaneous space or even into the peritoneum. Cerfolio [30] reported that SE occurs in 6.3 % of the patients after pulmonary resections. Although nonlethal, it may be difficult to convince the family members and other colleagues from the intensive care unit. A CT scan to identify an air pocket and to guide additional percutaneous drainage catheters may be helpful. Bronchoscopy may be required to exclude a bronchopleural fistula or a possible tracheal laceration during the intubation. Depending on the severity of SE, there are different methods of management, including observation, reoperation, and usage of pop-off valves. If reoperation is necessary, VATS or thoracotomy can be performed [30].

7.6 Chylothorax

A chylothorax is a leak of lymphatic fluid with chylomicrons and fats into the thoracic cavity. Chylothorax could be observed as milky or creamy pleural effusion coming from the chest tube in the early postoperative period or several days after surgery. It may occur as a result of a laceration of lateral branches of the lymphatic duct or direct iatrogenic duct injury and/or incomplete ligation of the lymphatic duct during some procedures, among which are extended mediastinal lymph node dissection, mediastinal tumor resection, esophageal resection, or extrapleural pneumonectomy [39]. The incidence after pulmonary resection is between 0.2 and 2.1 % and after esophagectomy 3.8 %, and the incidence rate also depends on the preference of mediastinal lymph node dissection techniques [39–43]. The diagnosis of a chylothorax is established if pleural effusion has a high level of triglyceride (>110 mg/dL), but if the level is between 50 and 100 mg/dL, lipoprotein analysis should be performed [41]. If triglyceride concentration is lower than 50, it is probably not a chylothorax. A persistent leakage may lead to albumin and antibody loss, malnutrition, and lymphocytopenia and increase the risk of bacterial and viral infections which is associated with significant postoperative morbidity and mortality [43]. In addition, an average daily chest tube output exceeding 400 mL in the early

postoperative period should prompt fluid analysis for chylothorax to facilitate early diagnosis and consideration of thoracic duct ligation [43]. The first choice in the treatment is to stop oral diet intake and immediately to start parenteral feeding. Daily drainage volume has been controlled, and decision whether to continue conservative treatment or to perform surgery has been made. Most of the postoperative chylothorax may be resolved by conservative therapy including octreotide/somatostatin infusion [42, 44, 45]. If the amount of the leak is low, it could stop at seal on its own, but before removing the chest tube, the patient should be given a fatty meal diet for two days, and if output is still nonchylous and the volume is low, then the chest tube is removed [40]. But if chylous leakage is greater than 2000 ml for the first 2 days, or as suggested by some authors greater than 1000 ml/per day for 5 days, reoperation should be performed without waiting any further [46, 47]. Lymphangiography and lymphoscintigraphy are useful to localize the leak [44, 45]. The alternative method of the management of the chylothorax is percutaneous catheterization of the thoracic duct and embolization [48].

7.7 Nerve Injury

Extended thoracic surgery may cause intrathoracic nerve injury (phrenic or recurrent laryngeal nerves). Most of the phrenic nerve injuries in literature are described after cardiac surgery, but it may also develop after thoracic surgery such as extended pulmonary resection, esophageal or mediastinal surgery, and cervical rib resection for thoracic outlet syndrome [49]. It may present with unilateral or bilateral diaphragm palsy and results in atelectasis, pneumonia, decreased pulmonary function, sleep-disordered breathing, and pulmonary effusion. It usually can be suspected when patient has decreased exercise tolerance or dyspnea. An intubated patient may have difficulties in weaning. X-ray demonstrates elevation of the affected hemidiaphragm, and ultrasound examination confirms the diagnosis [50]. The best treatment of choice is surgery, either diaphragmatic plication or phrenic nerve reconstruction for unilateral injury or diaphragmatic pacemakers in cases of bilateral injury [50–54]. In Fig. 7.2, you may see a patient with phrenic nerve paralysis and chest X-ray after VATS plication.

The recurrent laryngeal nerve has a high risk of injury during the dissection of the subaortic region, especially during pneumonectomy and esophagectomy, or in cases where patients received preoperative radiotherapy [55]. Recurrent laryngeal nerve palsy after mediastinal lymph node dissection may occur in up to 1.5 % and after esophagectomy up to 8 % but after left-sided pneumonectomy up to 30 % of cases [56–58]. The result of the injury is vocal cord paralysis, which is suspected if the patient has a weak or whispery voice or a weak cough or if the patient aspirates after water intake in early postoperative period; the last symptom should be differentiated from vocal cord edema in the very early postextubation period. When vocal cord paralysis is suspected, laryngoscopy or flexible fiber-optic laryngoscopy should be performed and followed by laryngostroboscopy and laryngeal electromyography. The management involves pulmonary physiotherapy to decrease risk of aspiration, medialization laryngoplasty with or without implant material, or

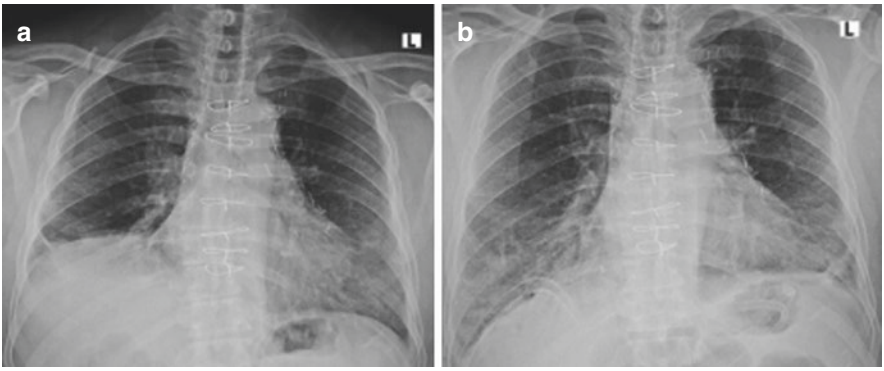

Fig. 7.2 (**a**) Chest X-ray view of a patient with phrenic nerve paralysis. (**b**) Chest X-ray view of a patient after VATS diaphragmatic plication

injection medialization [59–61]. Bilateral vocal cord paralysis is a catastrophe, which may occur after tracheal stenosis resection at the subglottic level. Experienced tracheal surgeons know the pitfalls and generally never have this complication.

7.8 Right-to-Left Shunt

Right-to-left shunt or platypnea-orthodeoxia syndrome is rarely observed after right-sided pneumonectomy operation or after an elevated right hemidiaphragm. The presence of a persistent foramen ovale (PFO) or open atrial septal defect can cause this syndrome. It is diagnosed by echocardiography or MRI. PFO is found in about 20 % of the normal population. Patients with PFO after pneumonectomy may not suffer from dyspnea and desaturation in supine position, but they may occur in sitting or upright position. Though PFO is normally asymptomatic, it is a potential source for a right-to-left shunt when the pulmonary artery and right heart pressure are increased [62–66].

Perkins [63] recommended including cardiac shunt in the differential diagnosis of hypoxemia, even in the presence of normal cardiac pressures, once other more common causes have been excluded. Transesophageal echocardiography may confirm the diagnosis. If the shunt persists, it needs percutaneous or surgical closure.

7.9 Atelectasis

Atelectasis is the collapse or incomplete expansion of the lung or part of the lung. It is one of the commonest abnormalities in chest X-ray after thoracic surgery, and it may be life threatening if not treated correctly. Atelectasis can occur in 15 % of the patients, and it is seen more frequently following right upper pulmonary resections [1, 67]. The cessation of smoking before surgery and preoperative

bronchodilators can help to prevent atelectasis. Predisposing factors for atelectasis after surgery are secretion retention, hypoventilation, pulmonary edema due to volume overload, decreased ciliary activity after sleeve resection, and COPD. Symptoms of the atelectasis are dyspnea, tachypnea, decreased respiratory sounds, tachycardia, and fever. Defined opacity, volume loss, fissure displacement, heightened hemidiaphragm, and mediastinal shift can be seen on a chest radiograph. Early pulmonary physiotherapy and nasotracheal aspiration are usually helpful in the postoperative period. Endobronchial aspiration and lavage with bronchoscopy may be performed (Fig. 7.3). The Thoracic Surgery Database had informed that about 3.7 % of atelectasis cases require bronchoscopy after lobectomy. Another helpful technique may be noninvasive positive-pressure ventilation and also effective pain management [5, 68, 69].

7.10 Postsurgical Empyema

Postsurgical empyema is the development of infection in the pleural space after esophageal, pulmonary, or mediastinal surgery. The incidence is higher in pneumonectomy (2–12 %) and may occur in 3 % of patients after lobectomy; the majority of these patients also present with a bronchopleural fistula (BPF) [5]. The incidence of the postsurgical empyema increases according to the indication of resection – inflammatory or neoplastic disease and the presence of a neoadjuvant therapy [70]. Risk factors include older age, cardiopulmonary impairment, malnutrition, induction therapy (especially chemoradiotherapy), diabetes, steroids, right-sided pneumonectomy, extended resections, postoperative pneumonia, and prolonged mechanical ventilation giving rise to barotrauma. Empyema can occur secondary to a spontaneous pneumothorax with persistent bronchopleural fistula [71]. PAL increases the risk of empyema up to 11 % [11]. Most of the cases develop in the early postoperative period (generally in first 3 months) but may occur also later (Fig. 7.4). The contamination of the pleural space develops from a BPF or esophagopleural fistula or from blood-borne sources. Clinical symptoms are mostly age specific and related to the general condition of the patient. The patient may be asymptomatic but may also have fever, fatigue, chest pain, dyspnea, and purulent or serosanguinous expectoration. The first sign of empyema is a change in the drainage pattern from serous to purulent, if the chest tube is still in place. And if it continues with air leak, the diagnosis of the BPF can be suspected. A pleural opacity with or without fluid level is usually detected on postoperative chest X-ray after lobectomy or segmentectomy. But after pneumonectomy, a decrease in the fluid level is visible. The most common bacterial pathogens are *Staphylococcus*, *Pseudomonas*, and anaerobic microorganisms. The treatment of the pleural empyema depends on the time of the diagnosis and the presence of the BPF and patients' general condition. The management includes antibiotic therapy and adequate chest tube thoracostomy with sensitive antibiotic solution irrigation to clean the remaining cavity [71]. After patient is stabilized (usually in 1–2 weeks), surgery may be performed. For empyema treatment,

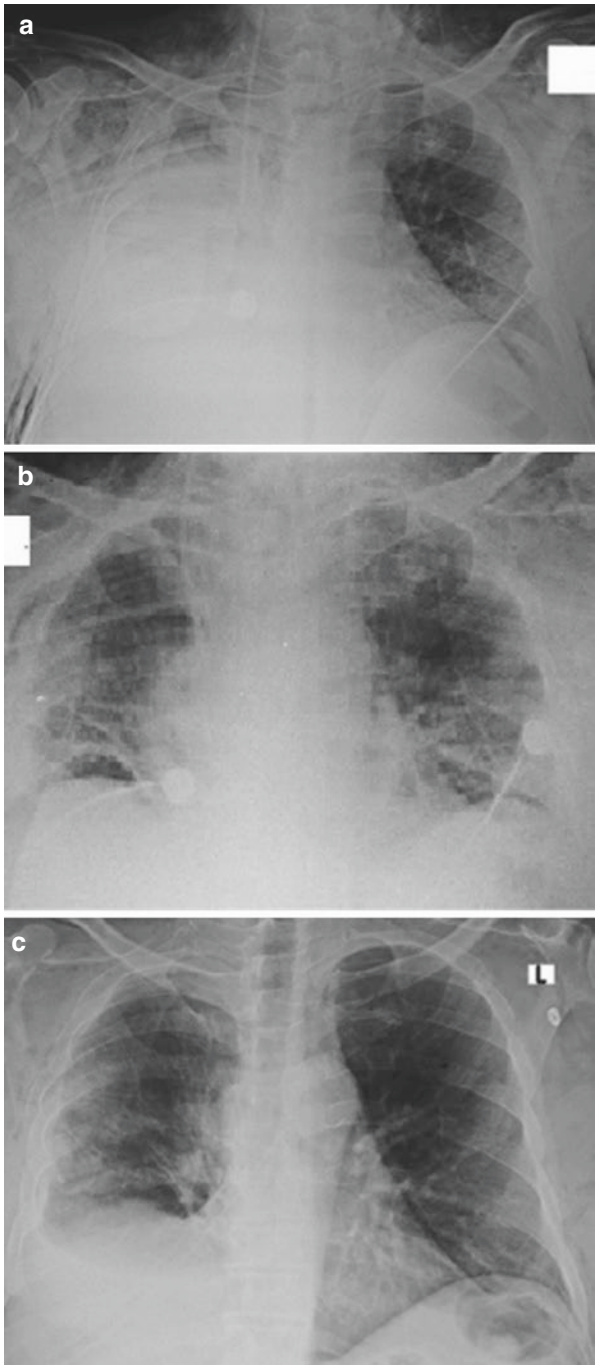

Fig. 7.3 Early pulmonary physiotherapy and nasotracheal aspiration are usually helpful in the prevention of postoperative atelectasis. Endobronchial aspiration and lavage with bronchoscopy help in the treatment of atelectasis. (**a**) Right lung atelectasis. (**b**) Immediately after the nasotracheal suction. (**c**) The next day with aggressive physiotherapy

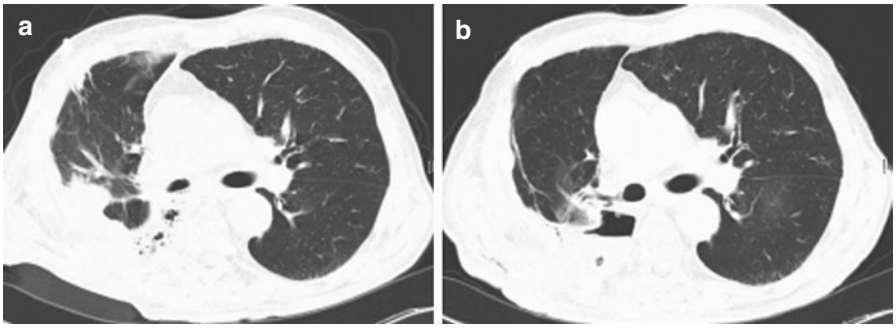

Fig. 7.4 CT scan view of a patient with empyema after lung resection (a–b)

surgeon may perform Eloesser procedure, myoplasty with muscle flap closure, thoracoplasty, or modified Clagett or Eloesser procedure [72].

7.11 Bronchopleural Fistula

BPF is a connection between the bronchus and pleural space. BPF ranges from small to large, the latter being a nightmare for thoracic surgeons often leading to life-threatening events. This complication leads to an increased morbidity and mortality after pulmonary resection. The overall incidence is 4.4 %, and it depends on the resection type [73]. Mortality rate is between 40 and 70 % of the patients with BPF after pulmonary resection [74, 75]. Risk factors of BPF include right-sided or completion pneumonectomy, surgery for infectious or inflammatory diseases, high-dose induction radiotherapy, prolonged mechanical ventilation, empyema, infected postresectional space, and residual tumor at the bronchial stump (Fig. 7.5). Most deaths are due to sepsis facilitated by aspiration pneumonia, ARDS, and malnutrition. Massive hemoptysis may be seen very rarely as a result of pulmonary artery erosion due to an infective inflammation. Most frequently a BPF is seen in 1 week after surgery [71, 72].

Small fistulas may be asymptomatic and close without any special treatment, but some BPF can lead to tension pneumothorax, aspiration pneumonia, and asphyxia. It can start with sudden dyspnea, excessive coughing, fever, fatigue, bloody sputum, and subcutaneous emphysema. In the case of tension pneumothorax, emergency chest tube drainage should be performed. If there is a suspicion of a BPF after pneumonectomy, the patient should be laid down on the operation side for protection of the opposite lung from contamination, and adequate chest drainage and antibacterial treatment should be performed [72]. Bronchoscopy is useful to confirm the diagnosis by demonstrating the presence of the BPF (Fig. 7.5). If there is no visible fistula and the suspicion continues, methylene blue injection to the bronchial stump may be performed; the drainage of the methylene blue via the chest tube is then diagnostic. During bronchoscopy, a balloon catheter may be inserted to see whether it stops the air leak. There is a typical decrease in the fluid level on the operated side after

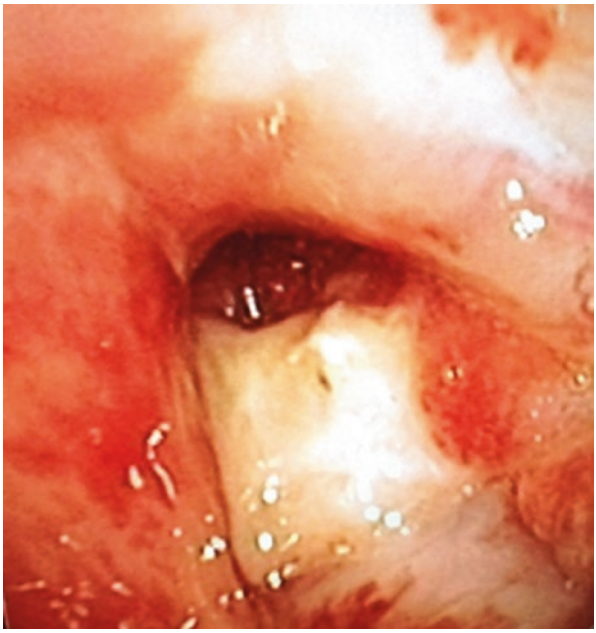

Fig. 7.5 Risk factors of bronchopleural fistula include right-sided or completion pneumonectomy, surgery for infectious or inflammatory diseases, high-dose induction radiotherapy, prolonged mechanical ventilation, empyema, infected postresectional space, and residual tumor at the bronchial stump. Bronchoscopic demonstration is the key to a definitive diagnosis

pneumonectomy. Also ventilation scintigraphy with inhalation of a radionuclide can be helpful for diagnosis. The definitive treatment should be chosen according to a diameter of the fistula and general conditions of the patient. The repair of the bronchial stump may be considered in pneumonectomy patients with early BPF (i.e., within 2 weeks). Open-window thoracoscopy can be performed for BPF with empyema treatment [71, 72].

7.12 Complications After Lung Transplantation

7.12.1 Vascular Anastomotic Complications

Complications of the arterial and venous anastomoses include stenosis, arterial kinking, and thrombus formation. Pulmonary artery stenosis has been reported in the early and late period after lung transplantation. There may be dyspnea, signs of pulmonary hypertension, and right heart failure (e.g., systemic hypotension, peripheral edema). Echocardiography may demonstrate an increased right ventricular pressure or right ventricular dysfunction. Quantitative ventilation/perfusion scan shows unequally distributed blood flow between the lungs after bilateral transplantation or disproportionate flow to the native lung after single-lung transplantation. Pulmonary angiography is usually necessary to confirm the diagnosis and helps in balloon dilatation or stent placement. Surgical reconstruction is the final option for stenosis not amenable to other interventions [73–77].

Kinking of the pulmonary artery is associated with decreased flow in the pulmonary vein, as assessed by transesophageal echocardiography [78]. Percutaneous placement of a metallic stent is recommended.

Pulmonary vein thrombosis occurs in the early postoperative period. Thrombus formation at the pulmonary venous/left atrial anastomotic suture line carries the risk of systemic embolization and cerebrovascular accident, and also it may obstruct pulmonary venous outflow and cause severe pulmonary edema refractory to medical management [79–81].

Clinical features include hypoxemia, decreased lung compliance, and diffuse radiographic opacities in the allograft. The diagnosis is made by transesophageal echocardiography.

There is no standardized management of the pulmonary vein thrombosis after lung transplantation. Fibrinolytic therapy can be useful, if the bleeding risk is not high [82]. Refractory hypoxemia and/or hemodynamic instability may require emergent surgical thrombectomy, but outcomes are usually poor. On the other hand, small venous anastomotic thrombi can resolve spontaneously [5, 83, 84].

7.12.2 Airway Complications

With the improvements in the surgical techniques and perioperative management of lung transplantation, the incidence of airway complications (AC) decreased to 10–20 % with a related mortality rate at 2–3 % [85–87]. Several risk factors for AC were identified: surgical technique, infections, and several immunosuppressive medications. The current recommendations are to avoid sirolimus at least 90 days after transplantation because of its antiproliferative properties. Donor and recipient risk factors could cause AC such as duration of donor's mechanical ventilation (50–70 h before organ retrieval) or difference between donor and recipient's bronchial diameters. Other risk factors may be primary graft dysfunction, acute cellular rejection, positive-pressure mechanical ventilation and need for a high positive end-expiratory pressure (PEEP), organ preservation technique, acute kidney injury, etc. Primary graft dysfunction, which is a type of reperfusion injury, may compromise pulmonary flow and increase the length of mechanical ventilation, and the high level of PEEP may be required. Positive-pressure mechanical ventilation and PEEP have a potential to increase the bronchial wall, and anastomosis stress and graft perfusion might be impaired when high inflation pressures are needed [88–92].

Bronchial stenosis is one of the common complications with a reported incidence between 6 and 23 % [93, 94]. It may be asymptomatic and diagnosed by routine bronchoscopy or may have a slight clinical symptom or manifestation of bronchial stenosis more frequently with increasing dyspnea, cough, post-obstructive pneumonia, or radiographic abnormalities. Bronchoscopy is a standard method for diagnosis. Management of bronchial stenosis includes balloon dilatation, ablation with cryotherapy, electrocautery or laser argon plasma coagulation, and stent placement [92, 95, 96].

7.12.3 Necrosis and Dehiscence

Isolated necrotic changes of the anastomosis may develop in patients undergoing transplantation, between first and fifth weeks. Necrosis can resolve quickly or can progress to the dehiscence. Early diagnosis is important. And if there is clinical presentation of prolonged air leak, pneumothorax, or pneumomediastinum, there exists the possibility of anastomosis dehiscence being a suspect too. Flexible bronchoscopy is a gold standard for diagnosis, and view of significant necrosis and loose sutures may be seen. Management of anastomotic dehiscence is surgical repair or even retransplantation [97].

Airway fistulas after lung transplantation are uncommon. Fistulas have been described between the airway and the pleura, mediastinum, aorta, pulmonary arteries, and left atrium. BPF is rare and may present with dyspnea, hypotension, sepsis, pneumothorax, subcutaneous emphysema, or persistent air leak. Endoscopic techniques for closing of fistula or surgical options can be used. Bronchomediastinal fistula has a high mortality, and the clinical presentation can be bacteremia, sepsis, mediastinitis, mediastinal abscess, or cavitation. Surgical treatment is recommended. Bronchovascular fistulas can present with minimal hemoptysis to fatal bleeding. These complications are rare but associated with high mortality. It should be suspected at the case of *Aspergillus* infection [97].

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