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REVIEW

Imaging findings of complications after thoracic surgery

Yeo Ryang Kang[1] · Jeung Sook Kim[1] · Yoon Ki Cha[1] · Yeon Joo Jeong[2]

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Abstract
Many surgical procedures are used for the treatment of lung, heart, and mediastinal diseases. The techniques can result in postoperative complications. The nature of these complications differs according to the duration of thoracic surgery and the onset of the complication. The complications occurring within 1 month and more than 1 month generally considered as early and late complications, respectively. Chest radiographs and CT scans obtained in patients who have undergone thoracic surgery show normal changes during the surgical procedure and diverse postsurgical complications. Familiarity with the clinical and radiologic findings of the normal alterations and possible complications after thoracic surgery is crucial in minimizing the increased morbidity and mortality.

Keywords Postoperative complications · Lung · Mediastinum · Multidetector computed tomography

Introduction

Many surgical procedures are used for the treatment of lung, heart, and mediastinal diseases. None of these surgical procedures is free of postoperative complications. Complications following thoracic surgery differ according to the duration of thoracic surgery and the onset of the complication (Table 1). The complications occurring within 1 month and more than 1 month generally considered as early and late complications, respectively [1]. Serial chest radiographs after thoracic surgery are an easy and inexpensive screening methods for some of these complications, especially atelectasis, pneumonia, and pulmonary edema. However, some of the complications are hard to detect subtle or equivocal on chest radiographs. CT is used to facilitate the diagnostic accuracy of the complications, because chest CT is superior to chest radiograph. It is important to recognize the radiologic findings of the normal alterations and potential complications after thoracic surgery for prompt and appropriate patient management.

Normal postoperative changes after lung surgery

Pneumonectomy

The initial changes in patients who have undergone pneumonectomy should demonstrate a midline position or minimum shifted mediastinum towards the pneumonectomy side and the presence of air within the postsurgical cavity. The rate of accumulation of fluid in the postsurgical cavity is variable [2]. In most cases, the pneumonectomy cavity is gradually filled with fluid and, within 4–5 days, is approximately half full (Fig. 1). The mediastinum gradually shifts towards the pneumonectomy side as a result of hyperinflation of the remaining lung and reabsorption of gas and fluid in the pneumonectomy space. Total obliteration of the pneumonectomy space usually takes weeks to months [2, 3]. Pleural fluid can exist for many years after surgery and should be distinguished from malignant effusion. Useful differential features are the presence of greater than 1 cm pleural thickening, discontinuous nodular pleural thickening, and mediastinal pleural involvement [4].

✉ Jeung Sook Kim
jeung-kim@naver.com

[1] Department of Radiology, Dongguk University Ilsan Hospital, Dongguk University School of Medicine, 27, Dongguk-ro, Ilsandong-gu, Goyang-si, Gyeonggi-do 10326, South Korea

[2] Department of Radiology, Pusan National University Hospital, Pusan National University School of Medicine, Pusan, South Korea

Table 1 Complications after thoracic surgery

Early complications	Late complications
Atelectasis	Bronchopleural fistula
Pneumonia	Thrombosis in the pulmonary vein stump
Pulmonary edema	Postpneumonectomy syndrome
Acute respiratory distress syndrome	Recurrence of primary disease
Lung torsion	Bronchial anastomotic stricture
Bronchopleural fistula	Postoperative intercostal lung herniation
Thrombosis in the pulmonary vein stump	
Anastomotic dehiscence	
Empyema	
Hemothorax	
Chylothorax	
Acute mediastinitis	
Cardiac herniation	
Deep sternal wound infection	

Lobectomy

After lobectomy, the chest radiograph demonstrates a decrease in ipsilateral hemithorax volume, diaphragmatic elevation, hyper-expansion of the remaining lung, and shifting of mediastinum toward the lobectomy side [5]. However, there may be little or no volume reduction effect after the right middle lobectomy [6]. Chest CT demonstrates bronchial stump, displacement of the fissures, and the ligated pulmonary vein [5].

Segmentectomy

Segmentectomy is a surgical procedure of the removal of only a segment of a lobe. Recently, most of segmentectomy is performed via video-assisted thoracoscopic surgery, as it reduces hospital stays, recovery times, and pain and risk for infection. Chest CT demonstrates resection of the segmental bronchus and ligation of the segmental pulmonary artery with preservation of the lobar bronchus [5].

Wedge resection

Wedge resection is preferred when patients have poor pulmonary reserve. This procedure reduces recovery times, rates of complications, and hospital stays. Both chest radiographs and CT demonstrate surgical materials, with or without thickening of adjacent soft tissue [5].

Sternotomy

After sternotomy, chest CT may demonstrate minimal soft-tissue infiltration with edema and blood in the presternal and retrosternal areas, gas bubbles, and mediastinal fluid collections. Mediastinal gas bubbles usually resolve by postoperative day 7, but can persist for 2–3 weeks. Only 50% of the patients undergoing sternotomies show complete healing of the sternum after 6 months, and sternal union should be complete within 1 year after the procedure [7, 8].

Minimally invasive surgery

Minimally invasive surgery is a surgical technique in which short, narrow tubes (trochars) are inserted through small incisions (less than 1 cm), which cause less scarring, decreased risk of developing complications after surgery, and faster recovery for the patient [9, 10].

Robot-assisted thoracic surgery

In robotic-assisted surgical system, surgeon is sitting at the surgeon console and manipulates the hand controls within the console. The robotic system provides the surgeon with a superior view of the operating field, which provides improved depth of perception compared with the conventional video thoracoscopic surgical cameras. Robotics seems to have longer operative time and higher hospital costs, but there is no difference in morbidity rates and oncologic efficiency between the robotic and thoracoscopic surgeries [11, 12].

Early postoperative complications

Atelectasis

Atelectasis is the most common complication after thoracic surgery. Atelectasis occurs in 5–10% of sleeve resections. It

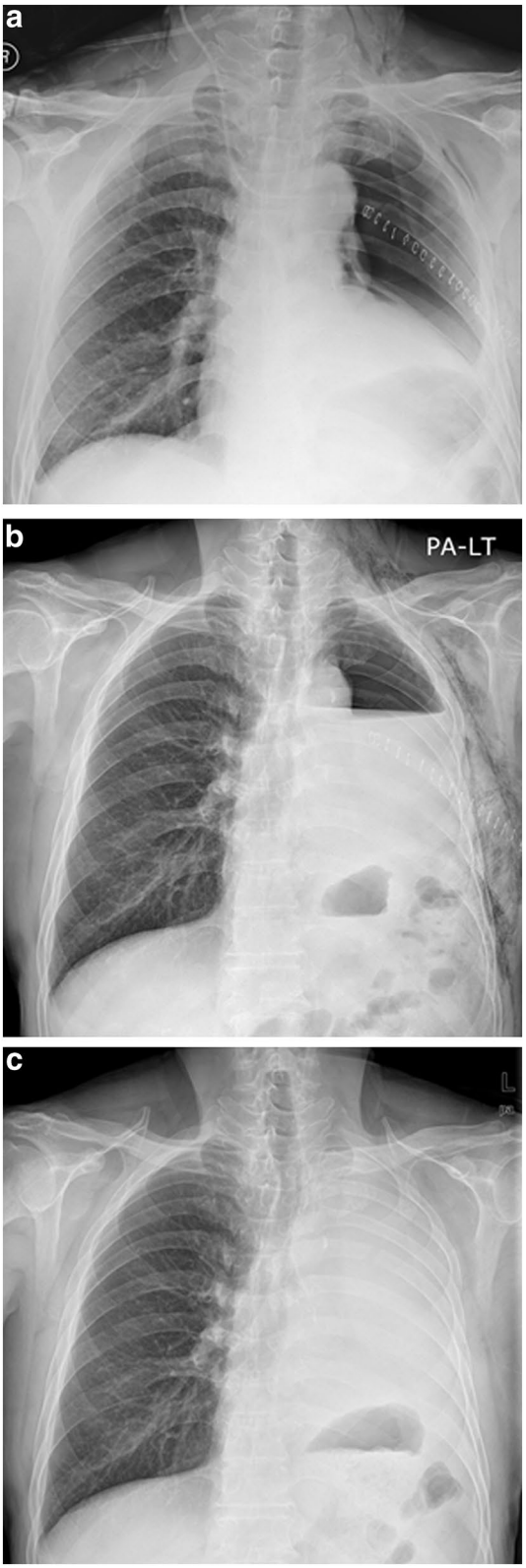

Fig. 1 Normal postoperative changes in a 70-year-old man treated with left pneumonectomy for squamous cell carcinoma in left lower lobe with direct extension into left upper lobe. **a** PA chest radiograph on postoperative day (POD) 1 shows pneumothorax in the postpneumonectomy space. **b** PA chest radiograph on POD 7 shows increased air fluid level in the postpneumonectomy space with mediastinal shift and tracheal deviation. **c** PA chest radiograph on POD 30 shows total opacification of the postpneumonectomy space with mediastinal shift and tracheal deviation

results from mucous plugging and subsequent lack of aeration of various parts of the remaining pulmonary parenchyma [5]. The atelectasis increased progressively until the postoperative day 4 and gradually improved. In some patients, infection may be superimposed on the atelectatic areas [1, 5]. CT findings of atelectasis are increased opacity with displacement of adjacent fissures and hemidiaphragm (Fig. 2).

Pneumonia

The reported incidence of postoperative pneumonia in the remaining lung ranges from 2 to 22% [1, 13]. Postoperative pneumonia is a result of aspiration of gastric secretions and bacterial colonization of atelectatic lung. Intubation and mechanical ventilation may increase the prevalence of aspiration and develop pneumonia. The transbronchial spill of fluid via a bronchopleural fistula may contribute to the prevalence of aspiration pneumonia [1, 13].

Radiographic findings may differ according to the type of bacteria colonization of the lung. In most cases, chest radiographs demonstrate patchy consolidation and lobar distribution less commonly observed (Fig. 3). Infection caused by aspirated contents may result in severe necrotizing pneumonia or abscess formation. CT facilitates the evaluation of aspiration pneumonia [1, 2, 13].

Pulmonary edema

Pulmonary edema is a potentially life-threatening complication with a reported prevalence of 2.5–5%. It is associated with mortality rates of 50–100% [13, 14]. Contributing factors pulmonary edema include increased hydrostatic pressure and altered permeability of capillaries [2]. Risk factors for pulmonary edema are excessive perioperative fluid load, transfusion of fresh frozen plasma, arrhythmias, postsurgical large volume diuresis, and low serum colloidal osmotic pressure [13, 14]. Postoperative pulmonary edema occurs more commonly after right pneumonectomy. As the left lung normally receives only about 45% of the total pulmonary blood flow, it is hard to support the increased fluid volume due to insufficient lymphatic capacity [13]. Postoperative pulmonary edema is diagnosed by excluding other diseases such as aspiration or bacterial pneumonia, heart failure,

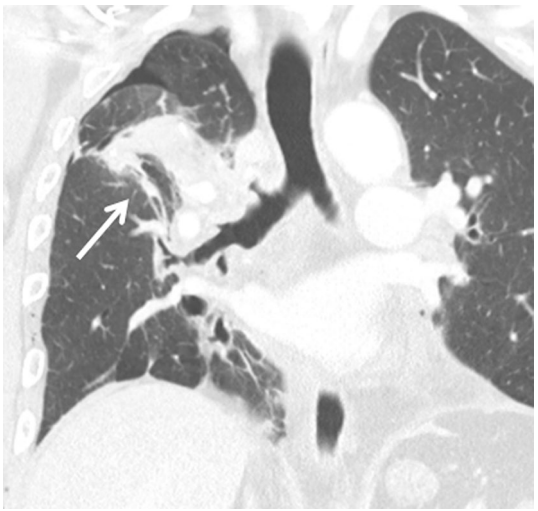

Fig. 2 Postoperative atelectasis of a 60-year-old man who had undergone right upper lobectomy for adenocarcinoma and left lower lobe basal segmentectomy for synchronous adenocarcinoma. Coronal CT image on POD 1 shows wedge-shaped consolidation (arrow) with crowding of bronchovascular bundles in the right middle lobe and elevation of right major fissure

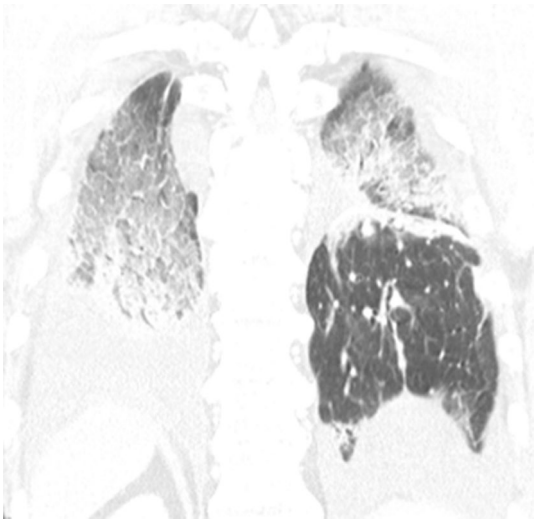

Fig. 3 Postoperative pneumonia in an 81-year-old man treated with right lower lobectomy and left lower lobe superior segmentectomy due to double primary lung cancer. Coronal chest CT image shows ill-defined ground-glass opacities and focal consolidation in both lungs

pulmonary thromboembolism, bronchopleural fistula, and acute respiratory distress syndrome [14].

Radiographic features include peribronchial cuffing, perihilar haziness, Kerley lines, and batwing opacification. These features generally disappear within a few days. In more severe cases, postpneumonectomy pulmonary edema manifests as diffuse airspace opacification [1, 2, 13]. CT shows smooth interlobular septal thickening, peribronchial cuffing, ground-glass opacities, and some consolidation (Fig. 4).

Acute respiratory distress syndrome

The reported incidence of postoperative acute respiratory distress syndrome (ARDS) after resection of lung parenchyma is approximately 5%. ARDS most frequently occurs after pneumonectomy with a mortality rate of more than 80%, compared with an overall mortality of 65% in all patients with ARDS [3, 13, 14]. Although the exact mechanism of ARDS is not proven, several factors are associated with its pathogenesis, including increased postoperative blood flow, lymphatic interruption, endothelial dysfunction, and hyperinflation [2, 13]. A PaO_2/FiO_2 ratio less than 200 is necessary for the diagnosis of acute respiratory distress syndrome [15].

Serial chest radiographs show rapidly increased diffuse opacities of the remaining lung [2, 13]. CT shows ground-glass opacities with anteroposterior gradient and interlobular septal thickening (Fig. 5).

Lung torsion

Torsion of the remaining lung or an individual lobe is a rare complication with a reported incidence of less than 0.4% [13]. The most commonly involved site is the right middle lobe after right upper lobectomy or the lingular segment of left upper lobe following a lingular segment sparing left upper lobectomy; however, other lobes can be involved [13,

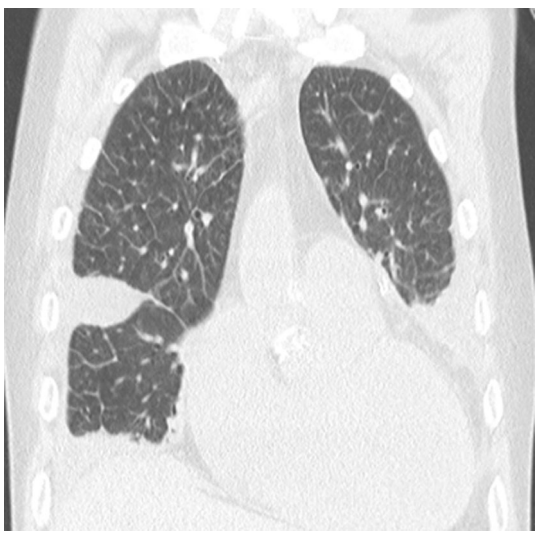

Fig. 4 Postoperative pulmonary edema in a 75-year-old woman treated with coronary artery bypass graft surgery. Coronal chest CT image on POD 4 shows smooth interlobular septal thickening in both lungs and bilateral small loculated pleural effusion

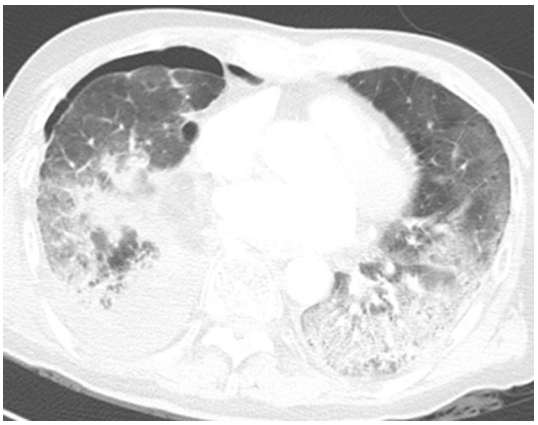

Fig. 5 Acute respiratory distress syndrome in a 78-year-old man treated with right middle and lower lobectomy for adenocarcinoma. Axial CT image on POD 21 shows extensive ground-glass opacities and consolidations in dependent lung. Small right pneumothorax is also noted. PaO_2/FiO_2 ratio of this patient is 128 mmHg

16]. Complete lung torsion is defined as rotation over 180°, and although, on occasion, 90° or 360° torsion has been reported. In complete lung torsion, obstruction of all the pulmonary vasculatures results in subsequent hypoxemia, ischemia, and hemorrhagic infarction or necrosis [13, 14, 16].

Chest radiographic features of lung torsion are lobar collapse or consolidation in an unusual position, marked change in position of the opacified lobe on short-term serial chest radiographs, displacement of the hilar structures, bronchial cut-off, and lobar air trapping. Chest CT may reveal tapered narrowing and obliteration of the proximal pulmonary artery and adjacent bronchus of the involved lobe, and amorphous soft-tissue thickening at the hilum (Fig. 6). Other possible changes include poorly enhancing consolidation with increased volume, interlobular and intralobular septal thickening, and ground-glass opacity [13, 14, 16].

Bronchopleural fistula

Bronchopleural fistula (BPF) can occur in either early or late postoperative periods, but a BPF is often seen within 8–12 days after surgery. BPF is a potentially life-threatening condition with a reported prevalence of 2–13% and an associated mortality rate of 30–70% [13]. BPFs are more common after right pneumonectomy rather than left pneumonectomy or lobectomy, probably because of the less effective coverage and shorter length of bronchial stump and the greater vulnerability to ischemia with blood supplied via a single bronchial artery. Postoperative positive mechanical ventilation is the most significant risk factor. Other risk factors include pleuropulmonary infection,

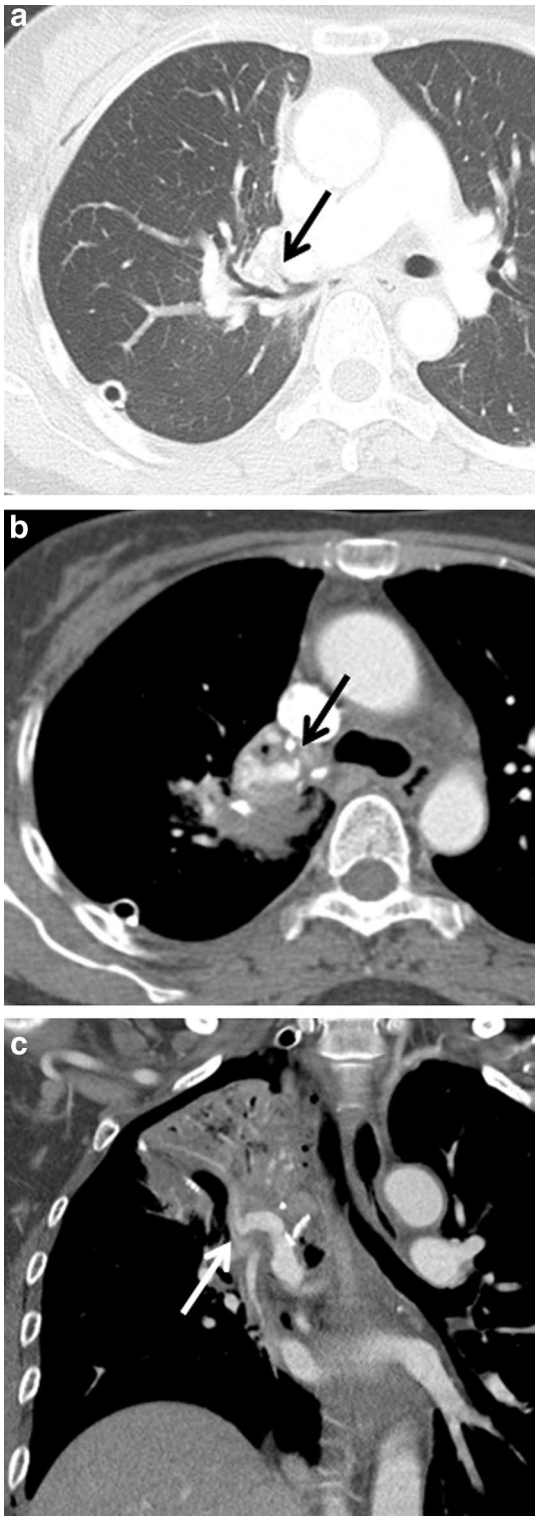

Fig. 6 Right middle lobe torsion in a 57-year-old woman treated with right upper lobectomy for adenocarcinoma. **a** Lung window setting axial CT image reveals occlusion of the right middle lobar bronchus (arrow). **b**, **c** Mediastinal window setting axial CT and coronal CT images show an abnormally rotated right middle lobar pulmonary artery (arrows). Right middle lobe was twisted 180 degrees on video-assisted thoracoscopic surgery

steroid use, leukocytosis, preoperative radiation therapy, and bronchoscopy for sputum suction [2, 13].

Radiographic findings of BPF are progressive or persistent pneumothorax despite adequate chest tube drainage, failure of the pneumonectomy space to fill with fluid, emphysema in subcutaneous and/or mediastinal area, and reappearance of air in a previously opacified pneumonectomy space [2, 13]. CT may demonstrate direct connection between the airway and the pleural space and an air fluid level in the pleural space (Fig. 7).

Thrombosis in the pulmonary vein stump

Thrombosis in the pulmonary vein (PV) stump is rarely seen after pneumonectomy, lobectomy, lung transplantation, or cardiac surgery. Thrombosis in the PV stump after surgery is possible to cause severe complications, such as infarction of vital organs [17]. Ohtaka et al. showed that thrombosis in the PV stump occurred in 3.3% of the patients undergoing lobectomy, and in 17.9% of patients who underwent left upper lobectomy. Therefore, contrast-enhanced CT should be recommended to evaluate thrombosis in the PV stump in patients who underwent left upper lobectomy with a high risk for thromboembolism [18].

Contrast-enhanced CT may demonstrate a well-defined polypoid filling defect in pulmonary vein stump with variable length of stump [17, 19].

Anastomotic dehiscence

An extended lymph-node dissection increases the risk of excessive tension on the bronchial anastomosis site and bronchial wall ischemia, leading to anastomotic dehiscence. Most of anastomotic dehiscence occur after sleeve lobectomy (up to 6%) and manifests as an early postoperative complication, which can lead to BPF [1, 13].

A defect in the bronchial wall is the most sensitive and specific CT feature for anastomotic dehiscence (Fig. 8). Other findings include bronchial irregularity, bronchial narrowing, extraluminal air surrounding the anastomosis, and pneumomediastinum [1, 13].

Empyema

Empyema is an uncommon complication, with a 2–16% risk in patients after lung resection. Empyema is associated with high mortality rates ranging from 16 to 71%, which may occur within 1 day or several weeks after thoracic surgery. In the early postoperative period, empyema is caused by residual infection in the pleural cavity. Furthermore, empyema occurs secondary to bronchopleural or esophagopleural fistula, and is associated with high mortality up to 71% [1, 2, 13].

The radiologic findings of postpneumonectomy empyema include straightening or convexity of the concave mediastinal margin of the pneumonectomy space, contralateral mediastinal shift, and thickening of residual parietal pleura (Fig. 9). Multiple air fluid levels may also be seen [20].

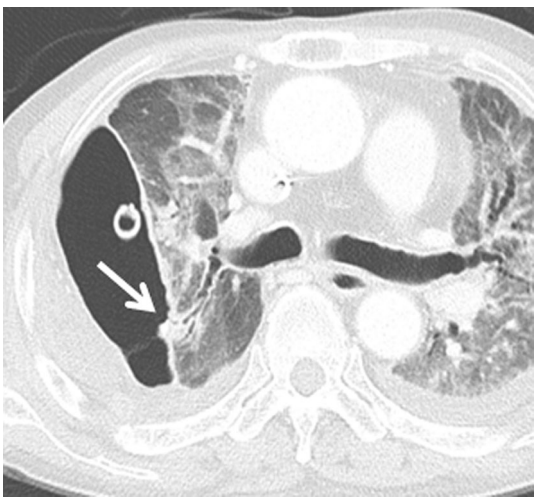

Fig. 7 Bronchopleural fistula in a 65-year-old man treated with wedge resection of right upper and lower lobes due to organizing pneumonia. Axial chest CT image shows the communication tract (arrow) between right lower lobe and pleural space. Air and fluid collections in the right pleural space are also noted

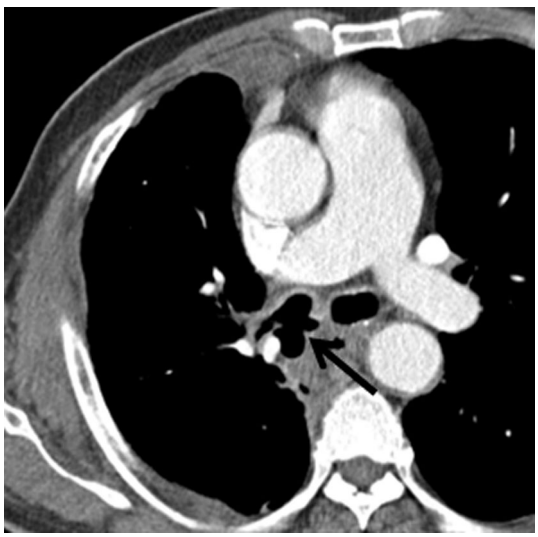

Fig. 8 Anastomotic dehiscence of bronchus in a 73-year-old man treated with right middle and lower lobectomy for squamous cell carcinoma. Mediastinal window setting axial CT image shows defective posterior bronchial wall (arrows) in the bronchial stump. Subsequent bronchoscopy demonstrated bronchial dehiscence

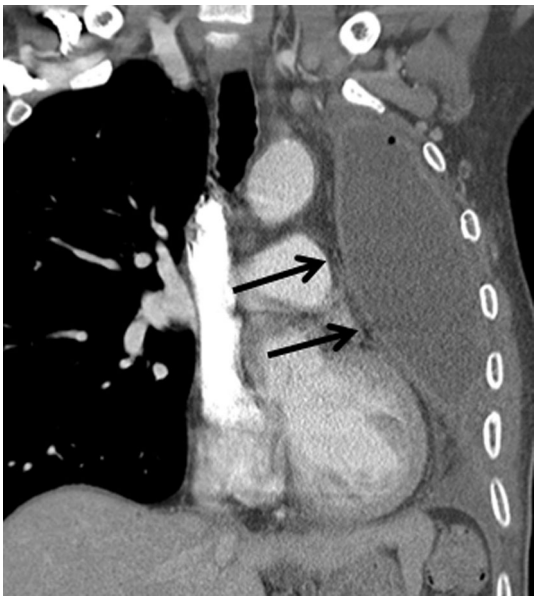

Fig. 9 Postpneumonectomy empyema in a 68-year-old man with poorly controlled diabetes mellitus and fever after left pneumonectomy for recurrent pneumonia. Coronal chest CT image reveals large amount of left pleural effusion with focal air pockets, irregular pleural thickening, and reversal of the normal concavity of the mediastinal pleura (arrows)

Occasionally, bronchopleural or esophagopleural fistula is found [2].

Hemothorax

Major hemorrhage into the thoracic cavity after thoracic surgery is usually the result of inadequate hemostasis of a systemic vessels or bronchial artery in the chest wall. Other less common causes include an unrecognized injury to a systemic vein, slippage from a major pulmonary vessel, and bleeding coagulopathy [1, 13].

On chest radiograph, hemothorax often manifests as rapid opacification of the postoperative space. CT demonstrates hemorrhagic pleural effusions as hyperattenuating areas of internal debris with fluid hematocrit level. Clotting and loculation of hemorrhagic pleural effusion may result in pleural pseudotumors. Pseudotumors can be characterized by their high attenuation compared with the other pleural masses on non-contrast CT scans [1, 13].

Chylothorax

Chylothorax is defined as lymphatic fluid accumulating in the pleural space caused by disruption of one of the main lymphatic vessels or the thoracic duct. Triglyceride concentration greater than 110 mg/dL in the pleural fluid strongly supports chylothorax [1, 13].

Fig. 10 Chylothorax in a 56-year-old man treated with right upper lobectomy and resection of 1-to-4th ribs for adenocarcinoma. Axial CT image shows a large fluid collection with focal low attenuation in the right hemithorax (arrow). The focal low attenuating area reveals − 4.2 H.U. and pleural fluid triglyceride level was 496 mg/dL

Postoperative chylothorax on chest radiographs is detected by rapid fluid filling of the operative site and resultant contralateral mediastinal shifting. The attenuation of chylous effusions on CT depends on its composition; the chylous effusions show low attenuation due to high fat content, particularly after a fatty meal, whereas the fluid with high protein content is higher in attenuation (Fig. 10) [1, 13].

Acute mediastinitis

Acute mediastinitis is a frequent postoperative complication. Most cases of acute mediastinitis are a postoperative complication of cardiovascular or other thoracic surgical procedures with a reported incidence of 0.4–5%. In the first 2–3 weeks, normal postoperative appearance of the mediastinum is quite similar to mediastinitis. However, persistence of mediastinal fluid collections and gas bubbles after 3 weeks is highly suggestive of mediastinitis [21, 22].

Chest radiographic findings include obliteration of normal contours of the mediastinal interfaces or lines, mediastinal widening, and diffuse or focal gas bubbles. CT images demonstrate increased attenuation of mediastinal fat, loculated fluid collections, gas bubbles in the mediastinum, pleural effusions, pericardial effusion, and presence of enlarged lymph nodes (Fig. 11) [21, 22].

Cardiac herniation

Cardiac herniation is a very rare complication following intrapericardial pneumonectomy with improper pericardial closure. It is associated with mortality rates of 40–50%. Cardiac herniation through a pericardial defect occurs in the immediate postoperative period or within 24 h after pneumonectomy. This complication is triggered

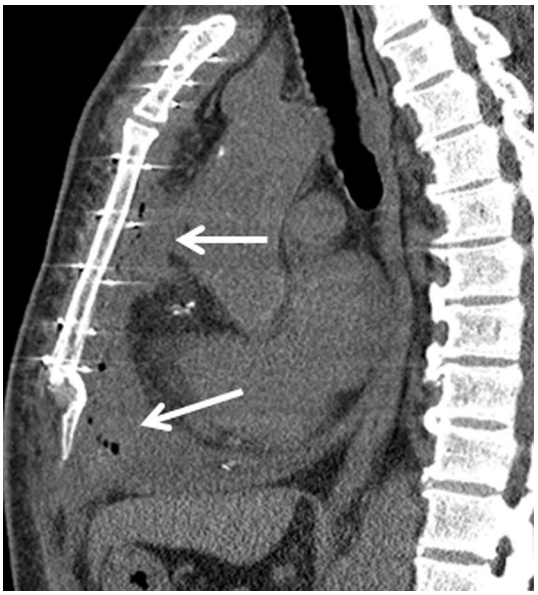

Fig. 11 Acute mediastinitis in a 52-year-old man treated with coronary artery bypass graft surgery. Sagittal CT image on POD 25 shows fluid collection with multiple air pockets (arrows) in anterior and mid mediastinum

by extubation, coughing, changes in a patient's position, or application of chest tube with negative pressure [2, 13].

Radiographic findings of cardiac herniation are pneumopericardium within the empty pericardial space. In herniation toward the right side, displacement of the cardiac apex to the right hemithorax produces superior vena cava syndrome. However, in herniation toward the left side, leftward herniation leads to prolapse of the ventricles and press coronary arteries by the edge of the pericardial defect [1, 2, 13]. In addition, the horizontal location of the herniated ventricular mass across the diaphragm, results in a "flattened boot" shape, and the cardiac shadow is not seen on the right side [1, 13].

Deep sternal wound infection

Deep sternal wound infection (DSWI) is a relatively rare (1.2–3.4%), but serious complication of cardiac surgery [23]. One of the most important tools for the prevention of DSWI is prophylactic antibiotic therapy. Risk factors include old age, obesity, diabetes mellitus, female gender, or hyperglycemia during the perioperative period, smoking, nasal carriage of *Staphylococcus aureus*, and skin infection anywhere on the body [24].

Chest CT shows fluid collections anterior to the manubrium and disruption of sternum (Fig. 12) [25].

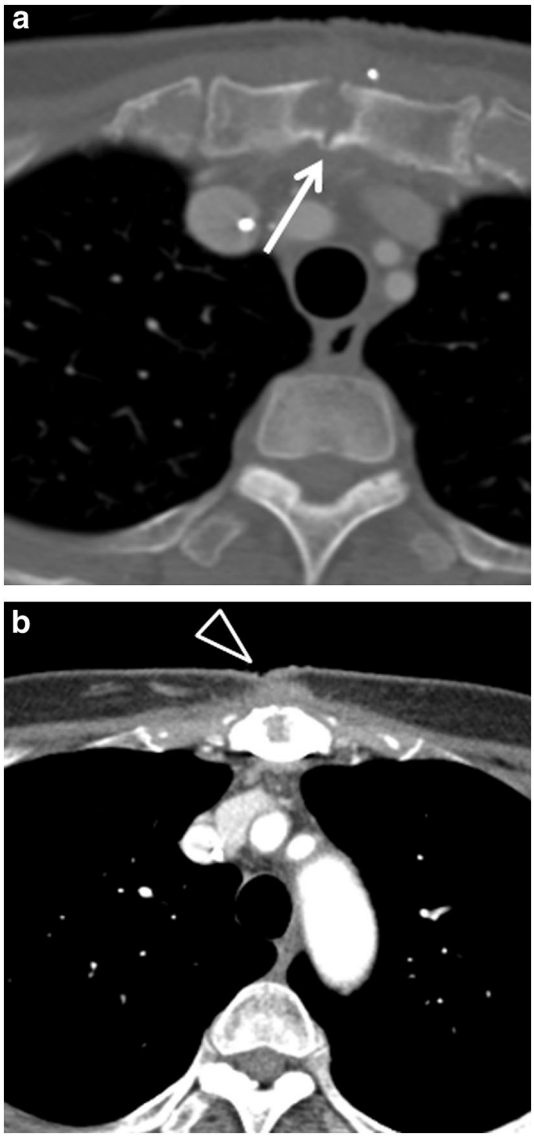

Fig. 12 Deep sternal wound infection in a 60-year-old woman who underwent mass excision of cardiac myxoma. **a** Axial bone window setting CT image shows ovoid osteolytic bone destruction (arrow) in sternotomy of manubrium, suggestive of osteomyelitis. **b** Axial mediastinal window setting CT image reveals ill-defined ovoid soft-tissue density mass (arrowhead) in anterior portion of osteolytic bone destruction and thickening of adjacent skin

Late postoperative complications

Postpneumonectomy syndrome

Postpneumonectomy syndrome is an uncommon complication characterized by dynamic airway compression caused by mediastinal shift and rotation after pulmonary resection [1, 14, 26]. This syndrome is most often seen in women, children, and young adults within 1 year after surgery. Most of postpneumonectomy syndrome occur following right

pneumonectomy because of the relatively large right hemithorax. Following right pneumonectomy, the heart descends into the hemithorax and rotates posteriorly, while the hyperinflated left lung shifts medially and anteriorly. The trachea is deviated toward the right, and consequently, the left main bronchus is stretched and compressed by the left pulmonary artery and the aortic arch [13, 26].

CT images depict compressed right main bronchus between the pulmonary artery anteriorly and the thoracic spine and aorta posteriorly (Fig. 13) [1, 13, 14, 26]. Postpneumonectomy syndrome is treated surgically with mediastinal repositioning and placement of saline-filled prostheses into the pneumonectomy space to prevent recurrences [27].

Recurrence of primary disease

Local recurrence of lung cancer with/without distant tumor recurrence was seen within 5 years after surgery in approximately 20–30% of patients with stage I disease, 50% with stage II disease, and 70–80% with stage III disease [2, 13]. Local tumor recurrences occur more frequently in the surgical margin or bronchial stump in patients who undergo segmentectomy or wedge resection than in those who have undergone a lobectomy [28].

The detection of recurrent tumor radiographically is a challenge. A contralateral shift of the mediastinum is a sensitive but nonspecific finding of recurrence, although this is a late finding. CT images demonstrate a recurrent tumor as a soft-tissue mass in or near the bronchial stump. It can also reveal other abnormalities such as enlarged mediastinal lymph nodes and pleural seeding (Fig. 14) [2, 13].

Bronchial anastomotic stricture

Bronchial anastomotic stricture is the most common late complication after a sleeve lobectomy with a reported prevalence of 18% and a potentially serious complication [1, 13]. This complication occurs due to granulation tissue, significant ischemia of the distal to the anastomosis, or anastomotic dehiscence with secondary healing and stricture formation [13].

Chest radiograph and CT demonstrate bronchial narrowing at the anastomosis site. Depending on the degree of stenosis, postobstructive atelectasis can occur [1, 13].

Postoperative intercostal lung herniation

Lung hernia is an uncommon complication, and postoperative pulmonary hernia secondary to minimally invasive surgery is even rarer [29], probably due to insufficient closure of the chest wall. Postoperative pulmonary hernia can be asymptomatic. However, the common complaint is a well-demarcated, soft, and compressible subcutaneous mass that is enlarged upon physical strain or coughing; diagnosis is confirmed radiologically [29, 30].

Chest radiographs and CT may demonstrate lung parenchyma outside the bony thorax, and rarely, incarcerated lung and necrosis (Fig. 15). Chest CT is needed to assess the location and size of the defect accurately [29, 30].

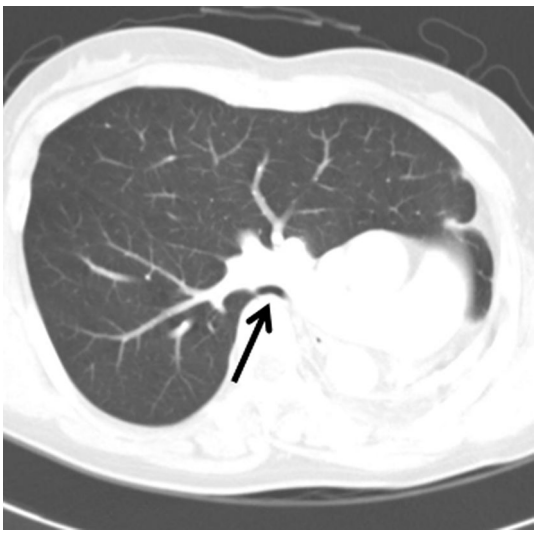

Fig. 13 Postpneumonectomy syndrome in a 51-year-old woman treated with left pneumonectomy for pulmonary tuberculosis. Axial lung window setting CT image illustrates stretching of the bronchus intermedius (arrow), which is visible between the right pulmonary artery and the vertebral body

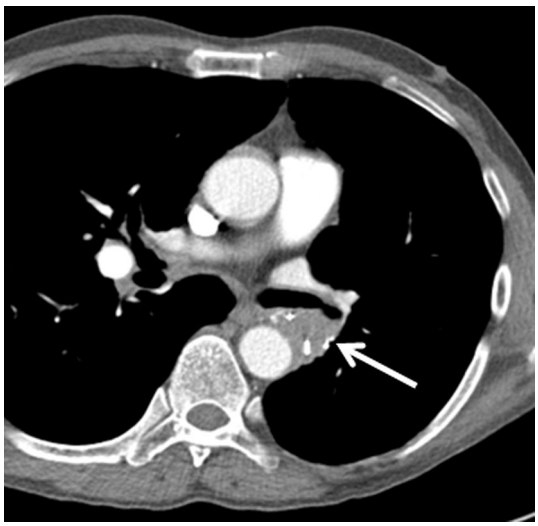

Fig. 14 Tumor recurrence in a 61-year-old man who underwent left lower lobectomy for squamous cell carcinoma. Axial chest CT image shows soft-tissue mass (arrow) in the lobectomy stump confirmed by bronchoscopy-guided biopsy

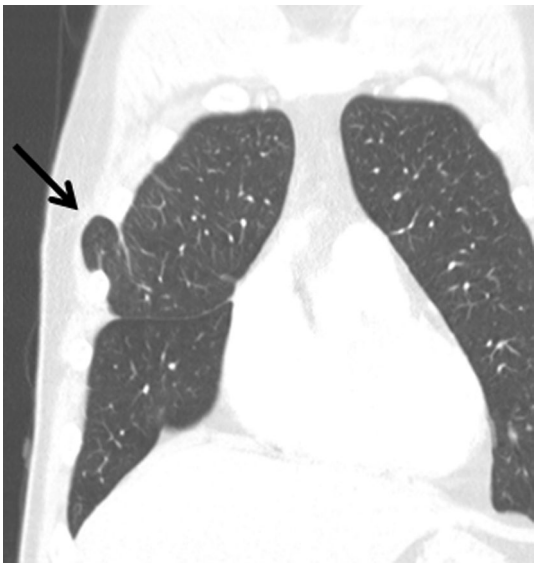

Fig. 15 Postoperative intercostal lung herniation in a 49-year-old man treated with minimal invasive cardiac surgery for mitral valve replacement. Coronal chest CT image shows intercostal lung herniation (arrows) in the anterolateral portion of right 4th and 6th ribs

Conclusion

Complications after thoracic surgery in the early and late postoperative period are diverse, and may involve life-threatening events, warranting prompt management. Chest radiographs and computed tomography (CT) are especially useful in the evaluation of complications related to thoracic surgery. Serial chest radiographs after thoracic surgery are an easy and inexpensive screening methods for some of these complications. However, some of the complications are hard to detect, subtle, or equivocal on chest radiographs. CT is used to facilitate the diagnostic accuracy of the complications, because chest CT is superior to chest radiograph. Therefore, knowledge of the radiologic appearance of normal alterations and diverse complications is crucial for the early diagnosis and initiation of appropriate treatment to reduce morbidity and mortality.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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