An Overview of Lung Surgeries: Postoperative CT Findings and Complications
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Citation

Abstract
There are various types of surgeries performed on the lungs, airways, pleura, and chest wall. As radiologists, it is imperative to understand the various surgeries, their expected post-operative imaging appearance and possible complications. The thoracic surgeries are broadly divided into two categories: open surgery and minimally invasive surgery. This article is a multi-modality review of open and minimally-invasive surgeries performed on the lung, pleura, trachea and chest wall. Computed tomography (CT) images, positron emission tomography (PET) images and radiographs, as well as intra-operative photographs and original illustrations of surgeries are provided to enhance understanding.

INTRODUCTION
Thoracic surgeons perform a variety of procedures depending on the indication, extent of disease and the health of the patient. Thoracic surgery interventions can be broadly classified into open and minimally invasive procedures (Fig. 1).

Figure 1
Figure 1: Classification of chest surgeries

Open surgery requires a thoracotomy or sternotomy, whereas a minimally invasive surgery requires the use of a thoracoscope, without the need for a thoracotomy. There are different types of surgical approaches such as partial sternotomy and neck incision for tracheal surgery, bilateral thoracosternotomy (clamshell sternotomy) for access to both lungs in metastatectomy and bilateral lung transplantation, and thoracotomy for unilateral lung surgery. Computed tomography (CT) is very useful in evaluating the post-surgical patient and in identifying complications.

DISCUSSION
Lung surgeries can be classified into non-anatomical and anatomical resections.

NON-ANATOMICAL LUNG SURGERY
Non-anatomical resection involves removal of a diseased portion of lung without complete dissection of the anatomic segment or lobe of the lung (including bronchus, pulmonary artery and pulmonary vein), and without removal of draining lymph nodes. The most commonly performed procedure is wedge resection, which involves resection of a non-anatomical “wedge” of lung (Fig. 2).

Figure 2
Figure 2: (a) Depiction of wedge resection. (b) Axial CT image shows uncomplicated right upper lobe (RUL) wedge resection. An opaque suture (arrow) with adjacent soft tissue is seen.

The indications for wedge resection are open lung biopsy for diffuse lung disease and pulmonary nodules, resection of metastatic nodules, and low grade lung cancer such as bronchioloalveolar carcinoma, and as a salvage procedure
for primary lung cancer. Another non-anatomical surgery is lung volume reduction surgery (LVRS) performed for severe emphysema, where the non-functional regions of both upper lobes (the maximal site of emphysema) are resected² (Fig. 3).

**Figure 3**
Figure 3: Axial CT images of the chest, before and after LVRS (a) Pre-operative: marked emphysema. (b) Post-operative: The more functional lower lobes have expanded and the major fissures have moved anteriorly; resection sutures are seen (arrow).

Another non-anatomical surgery is bullectomy, where large bullae are resected in patients with decreased functional lung volume or patients with recurrent pneumothorax.

**ANATOMICAL LUNG SURGERY**

Anatomic lung resection involves removing the diseased pulmonary segment(s), lobe(s) or lung along with the draining lymph nodes. Segmentectomy involves resection of a segment or any anatomic resection that is less than a lobe (Fig. 4).

**Figure 4**
Figure 4: Axial CT images following left upper lobe (LUL) upper division segmentectomy. (a) Uncomplicated surgery; LUL upper division bronchus stump (X), patent lingular bronchus (Y), and patent left lower lobe bronchus (Z) are seen. (b) Complication of a persistent air leak (asterisk) in a different patient. Chest tube is in place.

For example, a basilar segmentectomy refers to en bloc resection of all the basal segments of a lower lobe. Indications for segmentectomy are resection of bronchiectasis, benign tumor, localized low-grade lung cancer, and metastasis³, as well as lung cancer resection when lobectomy is not feasible due to pulmonary compromise. Lobectomy is the accepted definitive surgery for resection of most lung cancers⁴ (Fig. 5) and involves complete anatomic lobar resection.

**Figure 5**
Figure 5: Lobectomy. (a) Coronal CT demonstrates uncomplicated right upper lobectomy. RUL bronchial stump (s), displaced minor fissure (t) and scar (s) are seen. Complication of recurrent tumor (arrows) on axial CT (b) and positron emission tomography (PET) (c) images are seen in another patient. (d) Complication of esophagopleural fistula (t) between esophagus (t) and pleural space (s). Trachea (t) is noted anteriorly.

Pneumonectomy is the resection of an entire lung and can be divided into several types. Conventional pneumonectomy of either the left or right lung (Fig. 6) is necessary when there is proximal pulmonary arterial, pulmonary venous or bronchial involvement.
Figure 6
Figure 6: Pneumonectomy. (a) Fluid-filled left pneumonectomy space (f) with a smooth margin (arrow). (b) Complication of empyema with a thick irregular nodular wall (arrows) and convex medial margin. (c) Complication of postpneumonectomy syndrome. Post right pneumonectomy, the left main bronchus (arrow) is compressed between the right pulmonary artery (p) and the descending aorta (a).

Pneumonectomy is the procedure of last resort for tumor resection due to its higher mortality rate. Intrapericardial pneumonectomy is performed when tumor encroaches upon the hilum necessitating opening of the pericardium (Fig. 7).

Figure 7
Figure 7: (a) Coronal CT image post left intrapericardial pneumonectomy. Gore-Tex mesh (arrow) closes pericardial defect to prevent cardiac herniation. (b) Chest radiograph post right intrapericardial pneumonectomy. Cardiac herniation (asterisk) through the pericardial defect.

Extrapleural pneumonectomy, which is performed in selected cases of malignant mesothelioma and tuberculous empyema, involves resection of the lung and parietal pleura. The involved portion of the ipsilateral hemidiaphragm and pericardium are resected and reconstructed with prosthetic material (Fig. 8).

Figure 8
Figure 8: Coronal CT image status post right extrapleural pneumonectomy. There is pericardial and diaphragmatic resection and reconstruction with synthetic graft material (arrow).

To prevent bronchial stump dehiscence, a closure flap consisting of vascularized tissue is wrapped around the stump (Fig. 9).
Figure 9

Figure 9: Coronal CT image post left upper lobectomy. Alternating soft tissue and fat density represents the latissimus dorsi muscle flap (short arrows), which wraps around the bronchial stump (long arrow).

Examples of closure flaps include intercostal, latissimus dorsi and pectoralis muscles, and omental and pericardial fat pads.

AIRWAY SURGERY

Tracheal and carinal resection involves resecting a tumor or stricture in the airway, followed by reconstruction (Fig. 10).

Figure 10

Figure 10: Coronal CT images in tracheal resection. (a) Preoperatively, there is tumor (†) in the trachea. (b) Status post tracheal resection and reconstruction, there is slight indentation at the anastomosis (†), shortening of the trachea, and elevation of the carina (†).

Sleeve resection is performed for proximal endobronchial tumors and involves resection of a lobe and the adjacent airway “sleeve” of main bronchus or bronchus intermedius, followed by reanastomosis/ reimplantation of the remaining bronchi (Fig. 11).

Figure 11

Figure 11: Right upper lobe bronchial sleeve resection surgery. Pre-operative coronal CT image. Tumor (asterisk) extends via the right upper lobe bronchus into the junction with the main bronchus/ bronchus intermedius. (b) Original illustration of surgery demonstrating resection of airway sleeve (arrows). (c) Post-operative coronal CT image. There is narrowing of airway caliber (arrows).

PLEURAL SURGERY

Pleurodesis is performed for recurrent pleural effusion and recurrent pneumothorax, and involves administering a chemical substance (e.g. talc) via poudrage, or mechanically abrading the pleural space resulting in obliteration of the potential pleural space. F18-fluorodeoxyglucose (FDG)-uptake on positron emission tomography (PET) in the pleura following talc pleurodesis is an expected finding (Fig. 12).
Figures 12

Figure 12: Talc pleurodesis. The white powder in the intraoperative photograph (a), the high attenuation on CT (b), and the increased FDG uptake on PET imaging (c), all represent talc in the pleural space (arrows). Asterisk represents the deflated lung.

Decortication (removal of a thick peel off the visceral pleura) and pleurectomy (pleural resection) are procedures performed for empyema, organized hemothorax, fibrothorax, and tumor (malignant mesothelioma).

CHEST WALL SURGERY

Thoracoplasty involves resection of contiguous ribs and possibly intercostal muscles and underlying pleura, in order to obliterate a persistent pleural space in the setting of chronic infection and bronchopleural fistula (Fig. 13).

Open drainage (Eloesser flap) is performed for long-term drainage of chronic empyema, and involves creation of a fistula between the skin and pleural space, via a thoracotomy defect (Fig. 14).

Figure 13

Figure 13: (a) Axial CT image post left thoracoplasty. The left hemithorax is smaller; the remaining ribs are closely apposed (arrows); the left lung is collapsed.

Figure 14

Figure 14: Coronal CT image in a patient post right pneumonectomy complicated by bronchopleural fistula (arrows). The patient underwent open drainage surgery (Eloesser flap): a chest wall defect (D) was created and “Kerlix” pads (K) were inserted into the pneumonectomy space.
MINIMALLY INVASIVE SURGERY

Video-assisted thoracoscopic surgery (VATS) involves percutaneous insertion of a videothoracoscope into the thorax without performing a conventional thoracotomy14 (Fig. 15).

Figure 15

Figure 15: (a) Original illustration of VATS. A videothoracoscope and two other trocars for grasping and cutting are inserted through the intercostal spaces. (b) Axial CT post VATS wedge resection complicated by a hematoma (h). There is also a layering right pleural effusion.

The minimally invasive nature of VATS allows treatment of patients who are not candidates for thoracotomy due to medical comorbidities. VATS is associated with early recovery and less complications. Indications for VATS include biopsy/ excision of lesions in the lung, pleura, and mediastinum, biopsy of aorticopulmonary and bilateral hilar nodes, wedge resection, lung volume reduction surgery, lobectomy, and pleurodesis.

COMPLICATIONS OF THORACIC SURGERY

Specific early complications (post-operative day 0-30) related to technique include sutural dehiscence, lung herniation, bronchopleural fistula and cardiac torsion. Other general early complications include pneumonia, empyema, atelectasis, pulmonary embolus and infarction15. Late complications (post-operative day >30) include recurrent tumor, postpneumonecnectomy syndrome, and anastomotic stricture. Several of these complications, as well as additional ones, are illustrated above.

CONCLUSION

A large number of CT chest studies are obtained in the post-operative setting. Radiologists need to be aware of the different types of surgeries and their expected post-operative imaging appearance without and with complications.

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References

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