Diagnostic Imaging for Thoracic Surgery

A Manual for Surgeons and Radiologists

Michele Anzidei
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Foreword

Today, medical imaging is no longer the same as twenty or even ten years ago. The slice war in CT, the race to higher magnetic fields in MR and the development of novel contrast agents represent challenges of the past. The future of medical imaging now lies in artificial intelligence, machine learning, data mining and automation of diagnosis and interventions. And this is not a far future, rather the very next present.

To preserve our role in medicine, we will be called to reshape our professional skills and compensate automation rigidity with human adaptability. In this scenario, cross-specialty contamination is one of the human strength points as well as one of the daily challenges in clinical practice: the often over-animated debate between medical specialists in multidisciplinary teams represents in most of the cases the key to achieve optimal results for patients and will never be replaced by any software.

This is the inspiring concept at the very base of *Diagnostic Imaging for Thoracic Surgery*, in which the editors and authors aimed at conjoining shared points of view on non-vascular thoracic diseases with a large amount of high-quality images and line art, tables and updated guidelines, including latest 8th TNM for thoracic cancers and updated thoracic imaging guidelines.

Mostly written by enthusiastic and extremely competent radiologists, the aim of the book of providing an open and clear view on the role of medical imaging to thoracic surgeons, oncologists and pulmonologists is clearly and successfully reached, encouraging informed discussion in the daily clinical practice. As long as this continues to happen in our hospitals, we will be a step ahead of any machine.

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1 Preoperative and Postoperative Chest X-Ray

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Abstract

CXR is a first-line diagnostic tool for many clinical scenarios, since it is available in every hospital unit and is cheap in terms of costs and patients dose. Furthermore, it represents a wide-ranging point of view for the thoracic surgeon, allowing either pre-interventional evaluation and post-surgical monitoring.

Principal indication of chest X-Ray in the field of thoracic surgery include:

- Pre-operative assessment, the utility of which has been validated only for patients that present new\unstable cardiopulmonary disease;
- Post-operative follow-up, in order to evaluate surgery complications such as persistent air leakage, pneumonia, parenchymal atelectasis, empyema;
- Monitoring medical devices (pleural, esophageal, tracheal etc.)

By knowing specific chest X-Ray semiology, the physician is able to interpret the images obtaining clinical information.

Keywords

Chest X-Ray · Radiology · Chest imaging · Thoracic surgery · Cardiac surgery

Chest radiograph, or chest X-ray (CXR) in colloquial language, is the most frequently performed radiographic examination.

CXR is a first-line diagnostic tool for many clinical scenarios, since it is available in every hospital unit and is cheap in terms of costs and patient dose. Furthermore, it represents a wide-ranging point of view for the thoracic surgeon, allowing either pre-interventional evaluation or postsurgical monitoring [1].

This chapter briefly reviews CXR technique and addresses the pathological conditions assessable through chest radiograph which are considered of surgical interest.

1.1 Technical Considerations

Radiography utilizes electromagnetic high-frequency X-radiations, generated by a so-called X-ray tube (or generator) and captured by a photosensitive film or a digital detector.

High-voltage radiations (120–130 kVp) are advised to guarantee proper contrast resolution and to assure correct visualization of areas with complex anatomical structure (e.g., retro-cardiac

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region). Since high kVp significantly increases image noise, filtering devices integrated to X-ray generator have been introduced.

A chest radiographic exam may possibly comprehend many projections.

The classical ones are a posteroanterior view (PA) and a laterolateral view (LL), both obtained in end-inspiratory breath-hold (Fig. 1.1). For optimal reproduction of anatomical proportions, the more suitable distance between source and object should be at least 180 cm.

Inpatient radiographs are often performed bedside with portable X-ray tubes. This technology has significantly increased imaging feasibility for acutely ill subjects and posttreatment monitoring; on the other hand, portable CXR has lower diagnostic accuracy. In fact, anteroposterior view (AP) holds projective defects, especially regarding cardiac shape visualization (Fig. 1.2).

To better realize this issue, remind that cardiac shadow represents a significant part in CXR image and, if acquired on AP projection, it appears considerably magnified covering other structures and leading to misinterpretation of cardiac size (false cardiomegaly).

Furthermore, the absence of LL view makes accurate localization of lung findings extremely difficult and actually blinds radiologist's eye to some areas, as posterior pleural recesses.

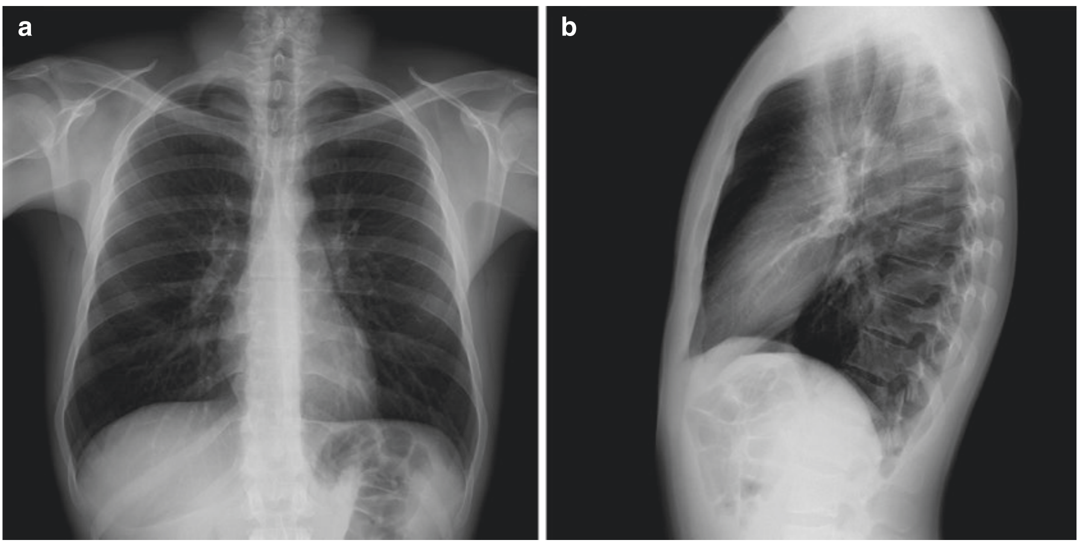

Fig. 1.1 Standard chest X-Ray PA (**a**) and LL (**b**) projections

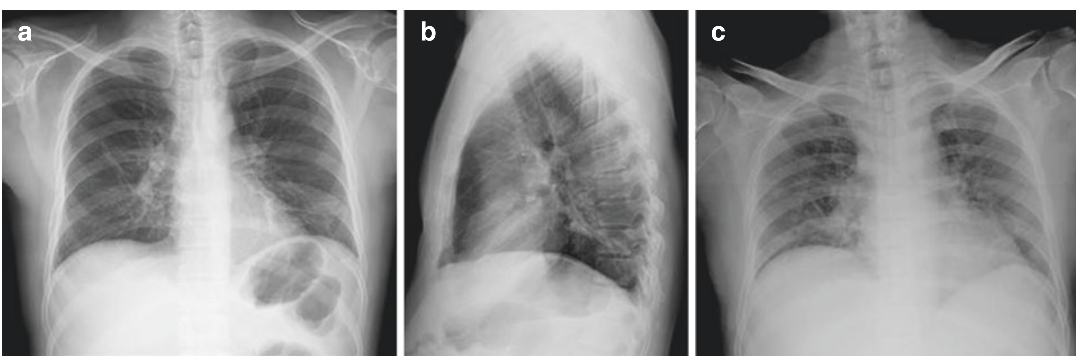

Fig. 1.2 Chest X-Ray projections: PA (**a**), LL (**b**) and AP (**c**)

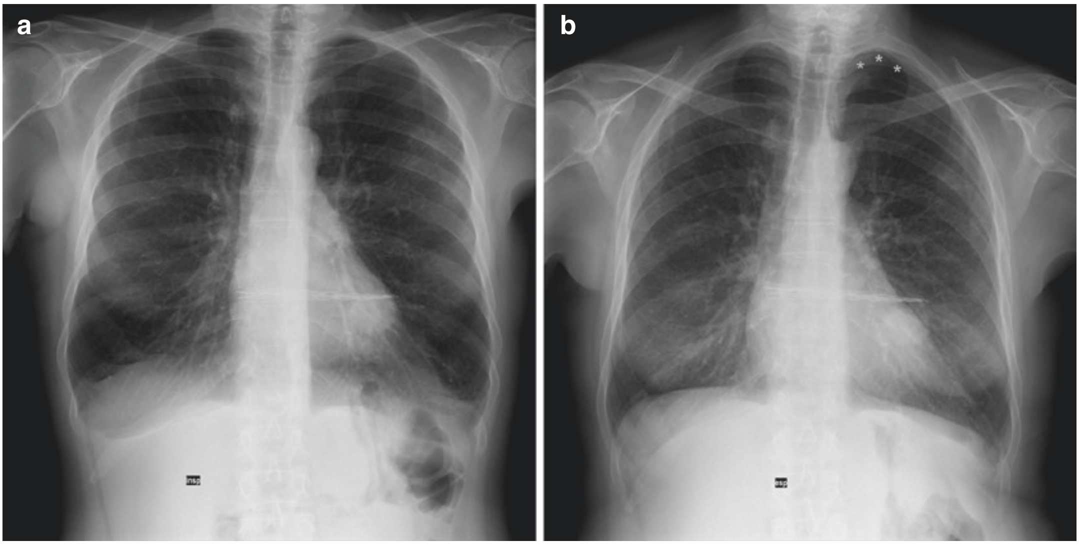

Fig. 1.3 Technical adequacy of CXR: uncorrect **(a)** and correct **(b)** image acquisition, with optimal visualization of bony structures, thoracic vessels and lung apices

As general principle, in routine imaging a double-view standard chest X-ray should always be preferred to a AP single-view exam. Portable radiographs are of basic importance in emergency and intensive care units, but in post-surgery patients a standard exam should be performed as possible.

Some dedicated projections comprehend:

– "Expiratory view" (Fig. 1.3), acquired in end-expiratory breath-hold to better evaluate the presence of pneumothorax.
– "Apical view," with superoinferior direction of X-radiation to show more clearly apical areas.
– "Oblique view," with 45° rotation of the patient between X-ray beam and cassette, useful for sternum and rib evaluation.

Technical adequacy of CXR exams is assessed, apart from a complete inclusion of the rib cage in the radiogram, by evaluation of X-ray's effective penetration across the thoracic structures (bony structures and pulmonary vessels are used as references), patient's rotation (clavicle heads should be equidistant to vertebral bodies), and inspiration (8th–10th posterior costal arches should be seen).

1.2 Lung Cancer Detection

Lung cancer is one of the leading causes of mortality in the world and its early diagnosis has demonstrated to relate with better prognosis; in light of this, screening programs of population at risk (heavy smokers) have been proposed by CXR and computed tomography (CT) imaging.

Chest radiograph has poor sensitivity on lung nodule detection (54%) despite its low cost and wide availability; on the other hand, volumetric CT, even with low-dose acquisition, encountered significantly higher sensitivity but still no evidence has pointed towards reduction of mortality for the populations screened by CT.

In modern practice, a negative CXR alone should not be interpreted as absence of neoplastic disease to lungs. In fact, pulmonary cancer detection on radiographs depends on some factors: lesion size, tumor localization, and density and secondary parenchymal changes.

The most challenging presentation of lung cancer in chest X-ray is as solitary nodule, the detection of which is deeply related to lesion location and volume. The main perceptive difficult for solitary nodule is anatomical structure superimposition that might hide pathologic findings; in this sense dangerous zones are represented by lung apices, diaphragmatic domes, and pericardiac and peri-hilar areas (Fig. 1.4).

Obstructive pneumonia/consolidation, hilar enlargement, and mediastinal enlargement are the main CXR findings that may highlight the presence of a central pulmonary neoplasm.

Obstructive parenchymal consolidation is due to bronchus obliteration by central located cancer (Fig. 1.5). Obstructive pneumonia affects more commonly a segment or a lobe and more rarely an entire lung; moreover it has been frequently associated to squamous cell carcinoma than adenocarcinoma.

Hilar enlargement is another radiological sign of central lung cancer and it is due to direct neoplastic infiltration, metastatic involvement of hilar lymph nodes, or both (Fig. 1.6). Notice that when metastatic lymph nodes are small in size, the only radiographic sign of hilar involvement may be an increment in density of its radiographic shadow.

Mediastinal direct invasion or enlargement of paratracheal and paraesophageal lymphnodes may cause another sign of central lung cancer, mediastinal shadow widening. Mediastinal involvement by cancer may determine paralysis of phrenic nerve with subsequent diaphragm relaxation that is assessable by CXR.

Peripheral lung cancer less frequently causes involvement of airways or other mediastinal structures; thus its diagnosis often occurs as an incidental finding of solitary

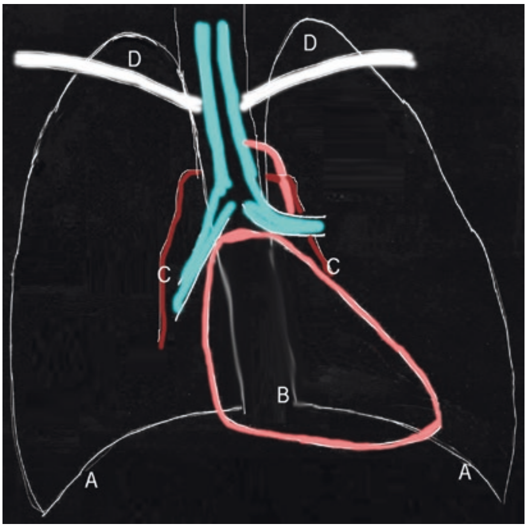

Fig. 1.4 Schematic representation of hardly evaluable anatomical zones on CXR: (**a**) diaphragmatic domes, (**b**) pericardiac areas, (**c**) peri hilar areas, (**d**) lung apices

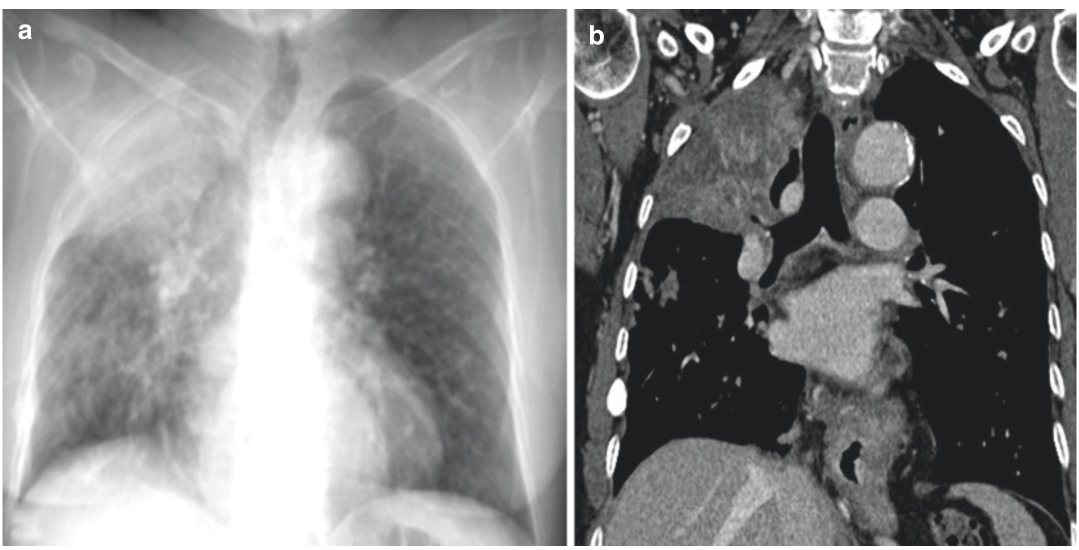

Fig. 1.5 Obstructive parenchimal consolidation on CXR (**a**) and CT (**b**) examination

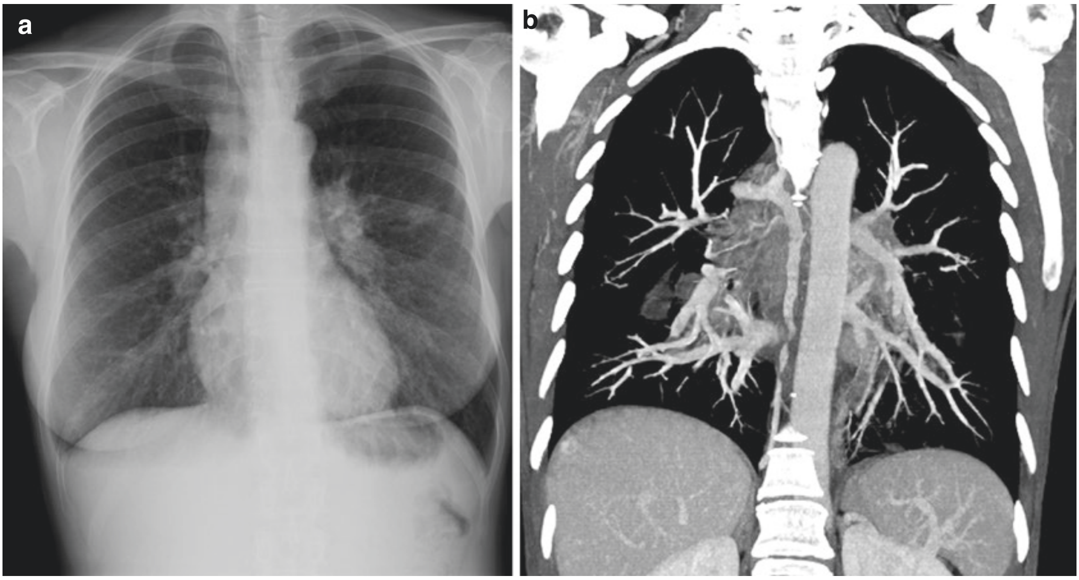

Fig. 1.6 Hilar enlargment on CXR (**a**) and CT (**b**) examination

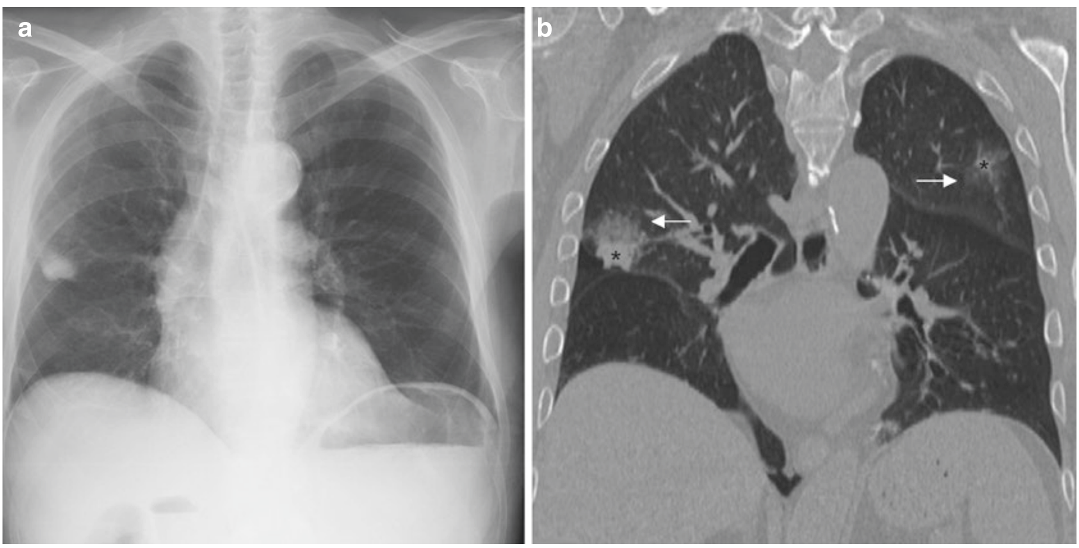

Fig. 1.7 Peripheral lung cancer on CXR (**a**) and CT (**b**) examination

nodule. Peripheral neoplasms are often more than 1 cm in diameter at the time of first diagnosis; nonetheless even larger sub-solid tumors may be overlooked due to their low-attenuation structure (Fig. 1.7).

Pleural effusion is associated with 10% of lung neoplasms (Fig. 1.8) and may reveal a hidden peripheral cancer that invades pleural layers.

1.3 Preoperative Screening

Historically a chest radiography was routinely acquired for any patient admitted to hospital to rule out asymptomatic tubercular infection. In modern surgical practice no significant benefit has been associated with preoperative screening CXR for asymptomatic patients with no cardiopulmonary disease history or risk factors.

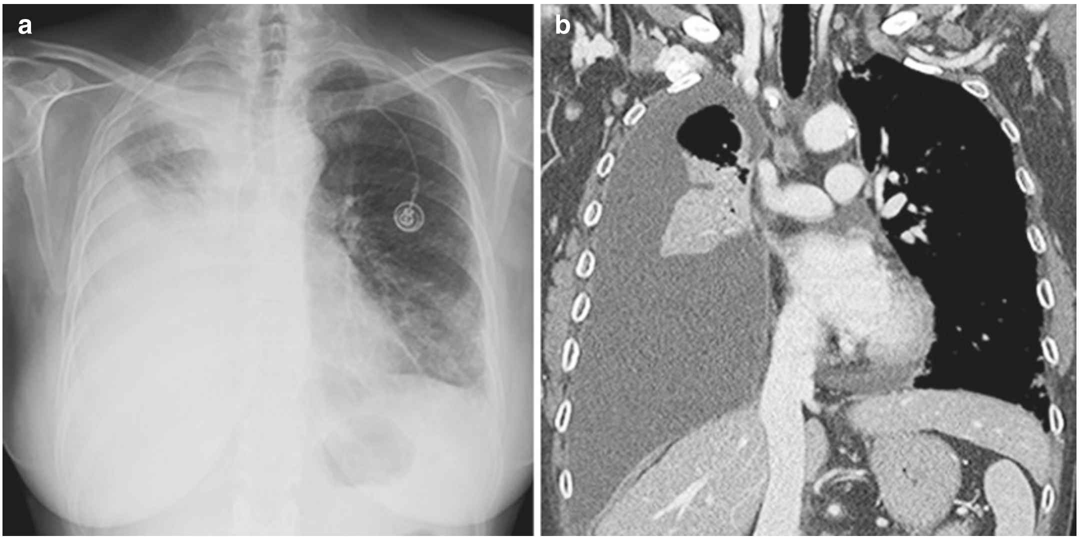

Fig. 1.8 Lung cancer- associated pleural effusion on CXR (**a**) and CT (**b**) examination

Even if some discordance is encountered among physicians' societies, guidelines generally agree that a pre-surgery chest radiograph is clearly indicated in patients with new or unstable cardiopulmonary signs or symptoms on physical examination (Table 1.1).

In daily practice, preoperative CXR is often advised on the basis of general performance status of the patient and grading of surgical intervention. American Society of Anesthesiologists (ASA) patients' classification is considered the most useful tool to standardize performance status into three classes (1 = healthy patient; 2 = patient with mild systemic disease; 3 = patient with severe systemic disease).

Abnormal findings at preoperative screening CXR are considered rare and often they are represented by chronic disease alterations, suspected on the basis of physical exam and history. Moreover, only rarely CXR findings are able to modify perioperative management of the patient or alter outcomes and clinical history of subjects at risk.

Thus, preoperative CXR rarely adds material to physical examination and anamnestic info in order to stratify surgical risk.

In conclusion, current statement on screening preoperative CXR does not warrant routine use of radiography to predict the risk of postoperative pulmonary complications; only patients with new/unstable cardiopulmonary disease should be

Table 1.1 Pre-operative chest radiography: guidelines

American College of Radiology, 2008	Chest radiography is usually appropriate for: - Patients with acute cardiopulmonary findings on history or physical examination - Patients older than 70 years who have chronic cardiopulmonary disease and have not had chest radiography in the previous 6 months
American Society of Anesthesiologists, 2002	Consider chest radiography for: - Patients who smoke - Patients with a history of recent upper respiratory infection patients with chronic obstructive pulmonary disease - Patients with cardiac disease However, if these conditions are chronic and stable, preoperative chest radiography is not necessarily indicated
Institute for Clinical Systems Improvement, 2012	Chest radiography may be considered for patients with signs or symptoms suggesting new or unstable cardiopulmonary disease

examined, if CXR findings may alter perioperative management.

1.4 Postoperative Chest X-Ray

The principal aim for radiologists who operate in a cardiothoracic surgical environment is to highlight every complication that may arise after an intervention. During postoperative course, complications of different nature and severity can arise and can be classified as immediate, early, or late, depending on the time of onset.

Approximately 16% of patients undergoing major surgical interventions will suffer from a complication within 30 days. In the field of thoracic surgery, incidence of pulmonary complications varies from 5% to 80% between different hospitals. Moreover, patients undergoing thoracic surgery are usually high-risk patients with a poor physical status [2].

Another routine use of chest X-ray after thoracic surgery is monitoring lung tube position; even though this evaluation is daily assessed for every patient in many institutions, no significant difference in terms of mortality, intensive care unit stay, or hospital length of stay has been demonstrated with CXR performed in selected cases [3].

1.5 Chest X-Ray Imaging of Lung Surgery Complications

In the immediate postoperative period, patients' imaging follow-up is assessed with portable equipment [4].

In case of major lung interventions (pneumonectomy/lobe resections) [5], CXR is usually performed in first and second postoperative days; then at the removal of the former and second drainage (fourth and fifth postoperative days); at discharge; and the at varying intervals depending on the clinical evolution (Table 1.2).

In patients undergoing sub-lobar resection (segmental or atypical) monitoring is performed with lower frequency, using X-ray evaluation in the first postoperative day, at removal of the single drainage (3–4 postoperative days), at discharge, and later in accordance with the clinical evolution (Table 1.3).

However, when radiographic findings are subtle or equivocal, CT frequently allows more accurate identification of the disease process as well as prompt and appropriate treatment [6].

1.5.1 Persistent Air Leak

Air leaks following major pulmonary resection are a well-known entity. Nearly all patients undergoing lobectomy or sub-lobar resection can be expected to experience some degree of postoperative air leakage. This condition is usually related to small parenchymal gaps produced during surgery, typically in the lysis of pleuroparenchimal adhesions or in the interlobar fissure completion; a higher incidence rate is observed in case of incomplete/absent interlobar fissures and in older patients with emphysema.

Most air leaks will stop within the first 1–2 days postoperatively; an air leakage lasting beyond 5 days is defined as persistent or

Table 1.2 Timing of chest x-ray evaluation after major lung interventions (pneumonectomy/lobe resections)

1st p.o.day	2nd p.o.day	3rd p.o.day	4th p.o.day 1st drainage removal	5th p.o.day 2nd drainage removal	discharge	Later in accordance with clinical evolution
•	•		•	•	•	•

Table 1.3 Timing of chest x-ray evaluation after minor lung interventions (segmental/atypical resection)

1st p.o.day	2nd p.o.day	3rd p.o.day	4th p.o.day drainage removal	5th p.o.day	discharge	Later in accordance with clinical evolution
•			•		•	•

prolonged and shows an incidence ranging from 5% to 10% [7, 8].

Chest radiography is able to depict persistent pneumothorax, pneumomediastinum, or subcutaneous emphysema.

Pneumothorax is defined as the presence of air in the pleural cavity, with secondary lung collapse.

The elective exam for the diagnosis of pneumothorax is standard CXR, performed in orthostatic position, with the additional acquisition of a forced-expiration imaging. However, the detection of the specific signs of this condition has a low sensitivity when CXR is performed in the supine position at bedside.

The characteristic sign on CXR is visceral pleural detection (as a radiopaque line) at the apex in orthostatic situation, with no evidence of pulmonary vasculature beyond the pleural edge (Fig. 1.9). The displacement of mediastinal structures, contralateral to the affected side, is evidence of hypertensive pneumothorax that is caused by pleural tear acting as one-way valve and requires urgent drainage.

On supine CXR diagnosis is more difficult because air moves up and medially between the lung and the heart; pneumothorax in supine position may be suspected in case of lucency at the hypochondria or at costophrenic angles (deep sulcus sign), and appearance of sharp edges of mediastinum, heart, and subcutaneous tissues (Fig. 1.10). When an air leak occurs in a preexisting pleural effusion it determines a specific finding, called hydro-pneumothorax, characterized by an air-fluid level inside the pleural space (Fig. 1.11).

Pneumomediastinum is a challenging radiological diagnosis; most common findings are represented by lucent streaks, bubbles of air outlining mediastinal structures, and visible mediastinal pleura [9].

1.5.2 Atelectasis

Postoperative atelectasis is a common issue following any major surgical intervention [10]. Thoracic surgical procedures increase the risk of this complication occurrence because pain, thoracic muscle injury, chest wall instability, and diaphragmatic dysfunction impair clearance of secretions by cough. In addition, patients with lung diseases are prone to increased bronchial secretions.

A wide range of incidence of this complication has been reported following pulmonary resection [11]. Incidence of lobar and segmental atelectasis after pulmonary lobectomy is reported

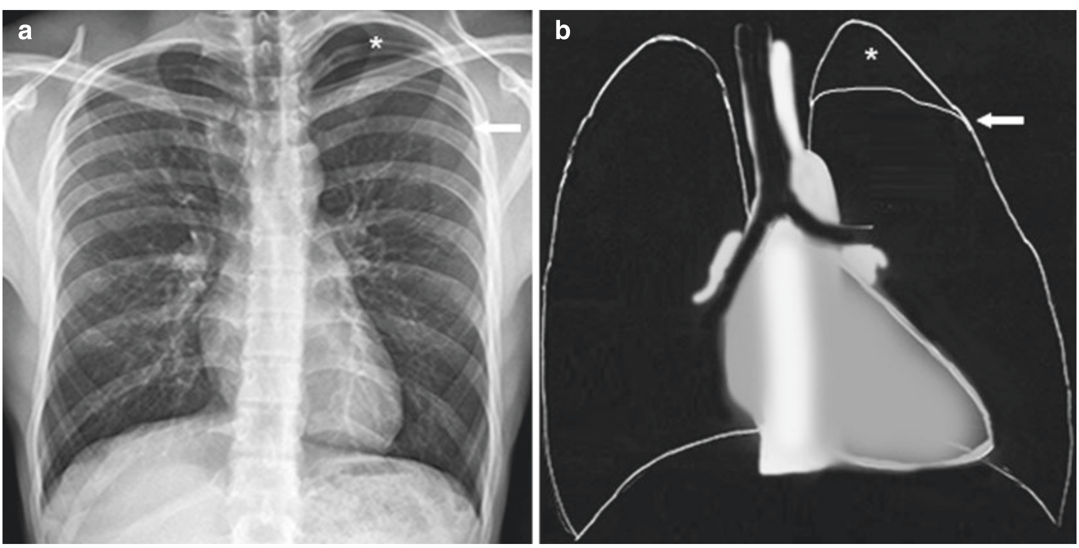

Fig. 1.9 Pneumothorax: standard CXR appearance (**a**) and schematic representation (**b**)

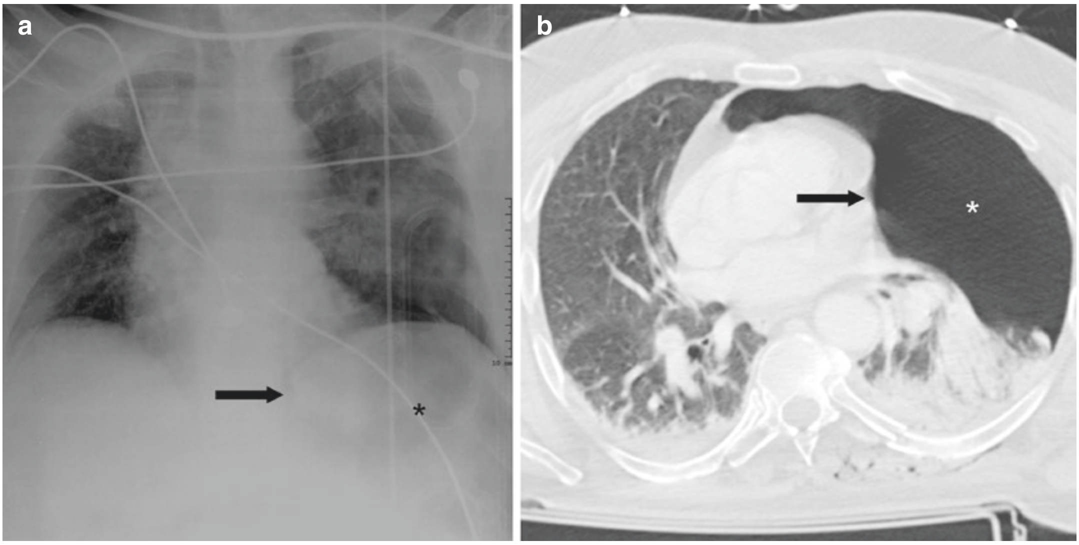

Fig. 1.10 Pneumothorax appearance on supine CXR (**a**) and CT (**b**) examination

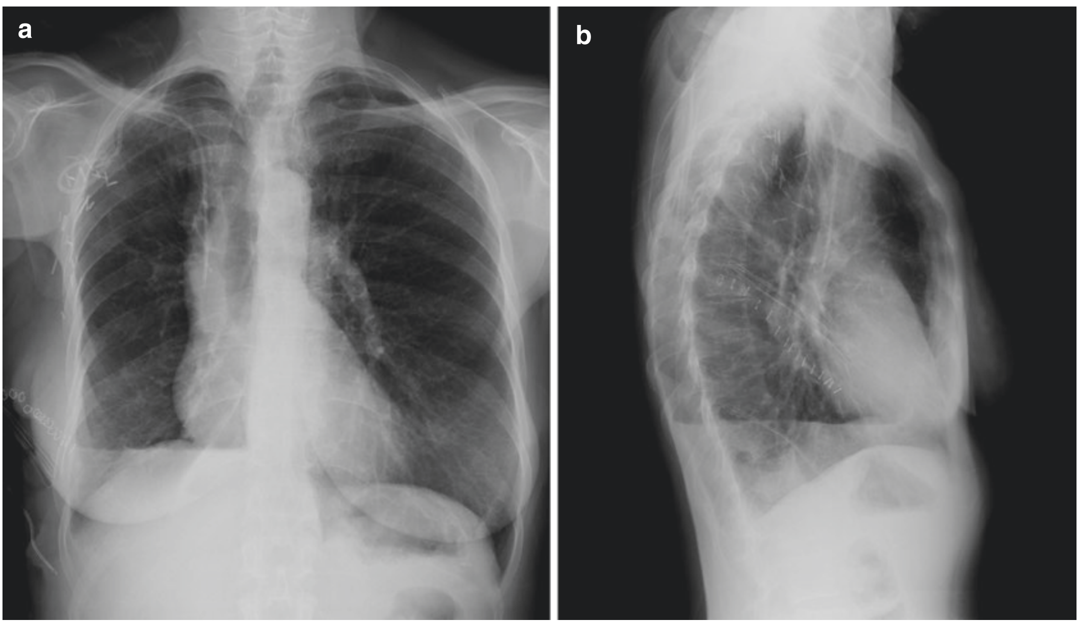

Fig. 1.11 Hydro-pneumothorax on standard CXR PA (**a**) and LL (**b**) projections

to be about 5–7%. Limited atelectasis is usually well tolerated and easily reversible. However, complete atelectasis of the remaining lung following partial lung resection may be poorly tolerated.

Classic chest X-ray findings include opacification of the remaining lung parenchyma and general signs of atelectasis relate to volume loss, as displacement of the interlobar fissures, hemidiaphragm rise, and attractive mediastinal shift. Usually, there is compensatory overinflation of the remaining aerated segments in the affected lobe, while collapsed area demonstrates sharp (often linear) borders.

1.5.3 Pneumonia

Postoperative pulmonary infection is observed in 2–22% of patients undergoing partial or total lung resection [12]. The main cause of this event is aspiration of gastric secretions and bacterial colonization of an atelectasis portion of residual lung, with intubation and mechanical ventilation representing predisposing factors [13]. In hospitalized patients the most common etiological agents are gram-negative, highly virulent organisms.

Radiographic findings may vary from patchy bronchopneumonic pattern to lobar airspace consolidation and necrotizing evolution of inflammatory collections (underlined by appearance of air-fluid level in the background of lung consolidations) (Fig. 1.12).

1.5.4 Bronchopleural Fistula

Bronchopleural fistula (BPF) is a pathologic communication between the pleural space and the bronchial tree and potentially represents a fatal complication of major thoracic surgery. Its incidence has decreased over the last few decades from 28% to 4%, but its mortality rate remains high (25–71%) due to aspiration pneumonia and subsequent acute respiratory distress syndrome.

BPF is frequently associated with postoperative mechanical ventilation [14].

Bronchopleural fistula is classified into immediate postoperative (due to faulty closure of the bronchus) and delayed postoperative (secondary to infection or recurrent tumor of the bronchial stump).

CXR may depict BPF as a localized collection with air-fluid level adjacent to bronchial stump (more commonly in the right hemithorax) or as decreases and increases over time of an already present air-fluid level (Fig. 1.13). Other radiological findings are represented by persistent pneumothorax despite drainage tube, progressive subcutaneous/mediastinal emphysema, and affected hemithorax volume enlargement.

1.5.5 Empyema

Empyema is a serious but uncommon complication of pulmonary resection, occurring in 2–16% of patients with high mortality rates (16–71%) and usually observed as bronchopleural fistula consequence [15]. Empyema is often associated with total pneumonectomy, preoperative irradiation,

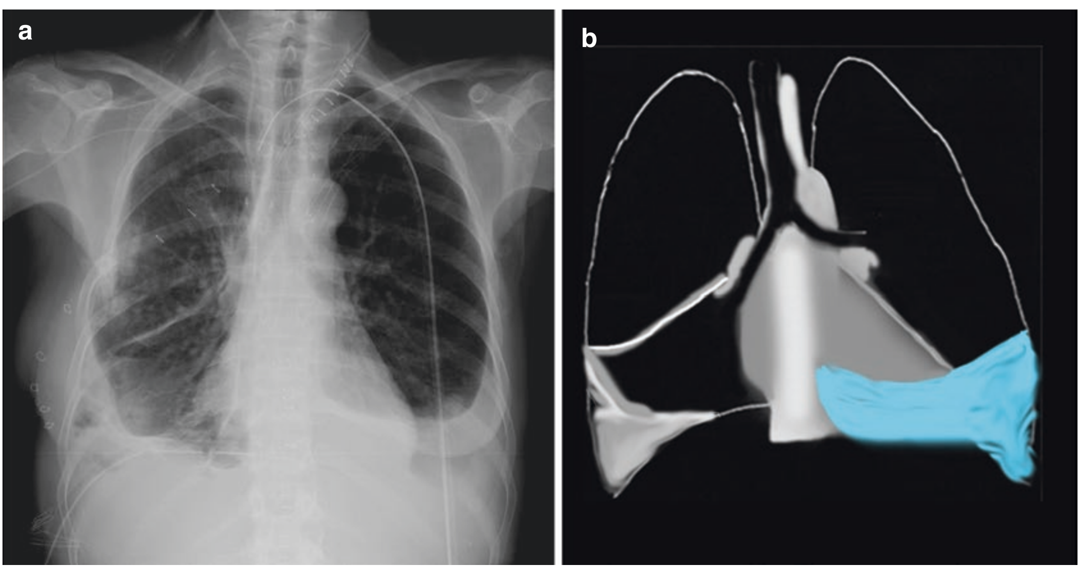

Fig. 1.12 Pneumonia: different radiographic findings (**a**) and schematic representation (**b**)

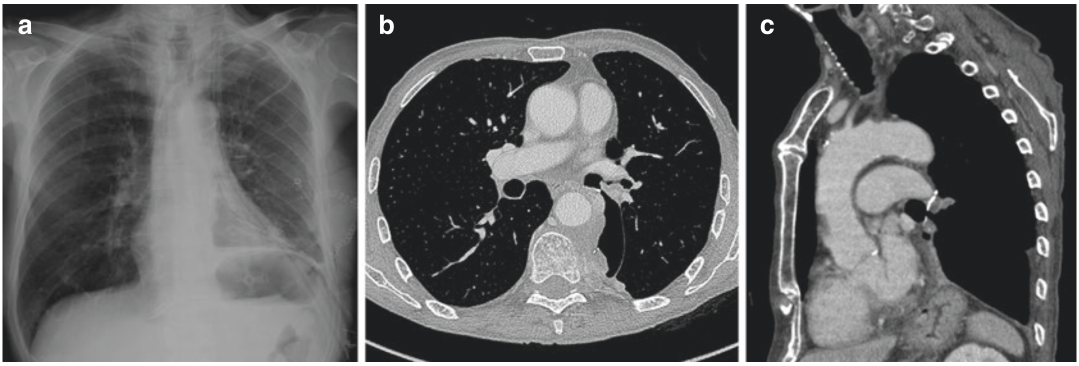

Fig. 1.13 BPF in the left hemithorax on CXR (**a**) and CT (**b**, **c**) examination

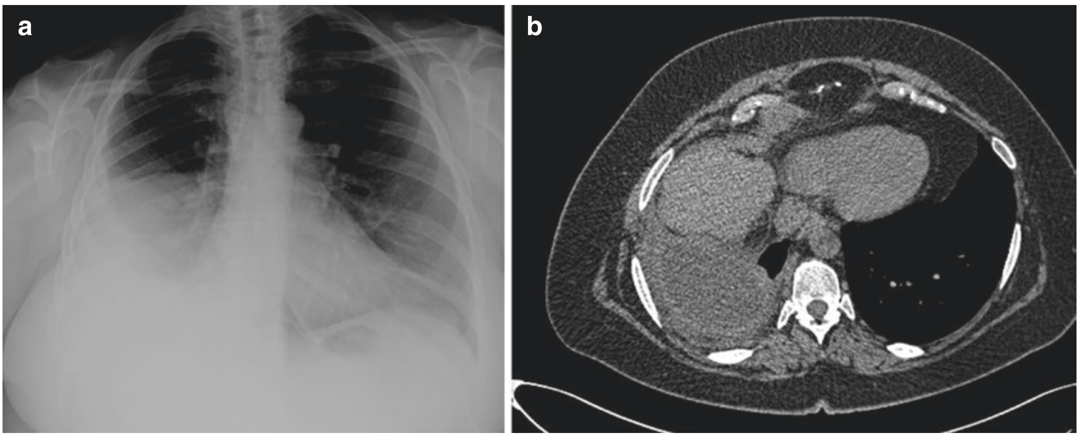

Fig. 1.14 Empyema appearance on CXR (**a**) and CT (**b**) examination

gross contamination of the pleura, long bronchial stump, and mechanical ventilation. It usually occurs in the early postoperative period, but can develop months or even years after surgery.

Postsurgical empyema is detected on CXR as a large radiopaque collection, often with multiple air-fluid levels. In chronic phase empyema is demonstrated by contralateral deviation of mediastinal structures (Fig. 1.14). Even the appearance of an air-fluid level in already opacified pleural space may be indicative of empyema.

1.5.6 Hemothorax

In the absence of deficiency of coagulation, the postoperative bleeding has an extremely low incidence, lower than 1%. Major hemorrhage following thoracotomy and resection is most commonly the result of inadequate hemostasis of a bronchial artery or systemic vessels in the chest wall. It infrequently results from the slipping of a ligature from a major pulmonary vessel or an unrecognized injury to a systemic vein.

CXR findings of hemothorax are nonspecific, mainly represented by significant amount of pleural effusion with fast onset and growth.

1.5.7 Chylothorax

Postoperative chylothorax is a rare but well-known complication of general thoracic surgery. It results from a massive chyle fluid leak (rich of rich triglycerides and chylomicrons) in the pleura, caused by thoracic duct injury [16].

Sites of potential thoracic duct injury during pneumonectomy include the inferior right hemithorax in the paravertebral area during extrapleural resection, the pericarinal and subaortic areas during radical nodal dissection, and the inferior pulmonary ligaments on either side during standard resection.

Radiographic findings are nonspecific and overlap with hemothorax appearance: pleural effusion with fast occurrence and expansion [17].

1.5.8 Acute Pulmonary Edema and Acute Respiratory Distress Syndrome

Acute pulmonary edema (APE) is defined as an abnormal accumulation of fluid in the extravascular compartment of the lung. It is a life-threatening complication that can develop 2–3 days after pulmonary resection, usually after pneumonectomy, lobectomy, or bilobectomy [18].

The most common cause of pulmonary edema in postsurgical period is an increased fluid overload.

APE is classified into two main groups, depending on different pathogenetic mechanisms: cardiogenic APE, due to increased hydrostatic pressure in pulmonary capillaries during congestive heart failure or fluid excess, and non-cardiogenic APE, due to increased capillary permeability during acute respiratory distress syndrome (ARDS).

In cardiogenic APE chest X-ray may show cardiomegaly, pulmonary venous hypertension, and pleural effusions [19]. Moreover, radiographic signs of cardiogenic APE include redistribution of blood flow to the nondependent portions of the lungs and the upper lobes (stage I), interstitial fluid collection with ill-defined vessels and peribronchial cuffing, as well as interlobular septal thickening (stage II) and peri-hilar and lower lobe airspace filling with features typical of consolidation (stage III) (Fig. 1.15).

ARDS is considered the most severe form of lung injury that can occur in patients who underwent thoracic surgery. Its overall incidence, observed after pulmonary resection, varies from 2% to 15% with a mortality rate reaching 80% [20].

This pathologic condition consists of an acute respiratory failure due to increased capillary permeability and usually occurs in the early postoperative days; however ARDS may also occur in association with other complications such as pneumonia or bronchopleural fistula.

Possible risk factors of ARDS after lung resection can be classified as preoperative (chronic obstructive pulmonary disease, chronic suppura-

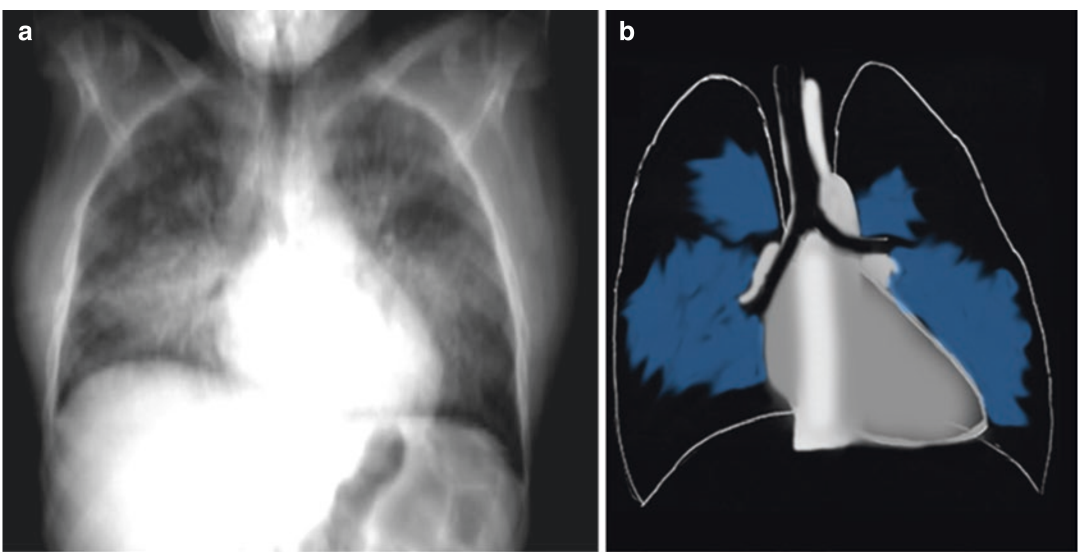

Fig. 1.15 Acute pulmonary edema (stage III): CXR appearance (**a**) and schematic representation (**b**)

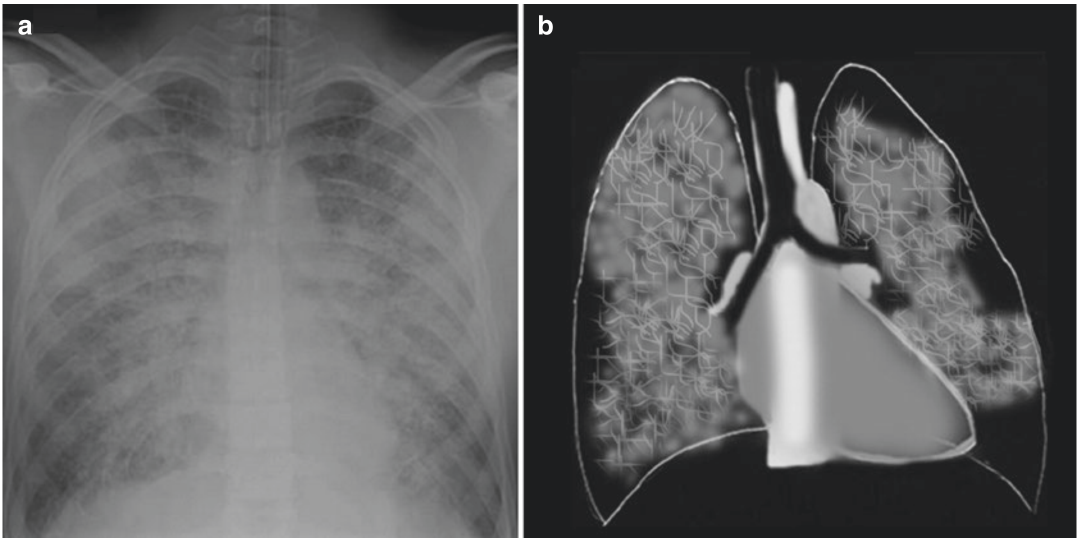

Fig. 1.16 ARDS: CXR appearance (**a**) and schematic representation (**b**)

tive disease, concurrent cardiac disease, low diffusion capacity for carbon monoxide, prior therapy), intraoperative (pneumonectomy, excessive perioperative intravascular volume, duration of operation), and postoperative (nonbalanced drainage of hemithorax after pneumonectomy.

Chest X-ray, more often negative in the first 24 h after the onset of clinical symptoms, shows the rapid development of extensive opacities with homogeneous or asymmetric and "patchy" distribution that don't spare the periphery of the mid or upper lungs, as observed in hydrostatic pulmonary edema. In non-cardiogenic causes, moreover, cardiomegaly and pleural effusions are usually less evident (Fig. 1.16).

1.6 Chest X-Ray Imaging After Cardiac Surgery

Post-cardiac surgery chest radiograph is routinely used to detect hemothorax or other pleural effusion. After removal of the chest tube, radiographs have traditionally been obtained to exclude pneumothorax or any other abnormality requiring intervention.

However, many studies demonstrate that chest radiography after chest tube removal following cardiac surgery is necessary only if the patient has respiratory or hemodynamic changes or if there are problems with the technical aspect of chest tube removal.

There is evidence presented that routine post-drain removal chest radiography provides no diagnostic or therapeutic advantage over clinically indicated chest radiography or simple clinical assessment [21, 22].

On the other hand, minimally invasive cardiac surgery patients represent a population that might benefit from routine CXRs after surgery, permitting prompt diagnosis of pathological condition related to the place of surgical access (pneumothorax, subcutaneous emphysema), temporary one-lung ventilation technique (atelectasis), less surgical field visualization and hemostasis (hemothorax), or need for invasive device placement (pulmonary artery catheter, temporary transvenous pacing wire) [23].

1.7 Chest X-Ray Imaging of Thoracic Surgery Devices

In postsurgical chest X-ray several medical devices may be encountered; radiologist ought to recognize each of them assessing their proper positioning.

Medical devices can be classified into pleural, tracheal, esophageal, and cardiovascular.

1.7.1 Pleural Devices

Pleural drainage catheters, often referred as chest tubes, are placed lying inside the space between parietal and visceral pleura through thoracostomy access. Their function is to evacuate effusion or air collections.

Notice that fluid effusion is often evacuated by tubes placed at lung bases while pneumothorax requires a drain placed at apices (Fig. 1.17). Not infrequently pigtail and flexible catheters are used to drain loculated collections.

Chest tube erroneous positioning must be recognized utilizing proper radiographic views (e.g., latero-lateral projection) and clinical information. Other technical complications following drain catheter insertion may be intra-fissure or extrapleural placement (even in thoracic wall structures) and tube kinking.

1.7.2 Tracheal Devices

Endotracheal tubes (ETT) are fundamental to guarantee assisted ventilation, a lifesaving care. Two different types are recognizable by CXR: endotracheal cannula and tracheostomy tube (Fig. 1.18). They are cuffed and placed in the

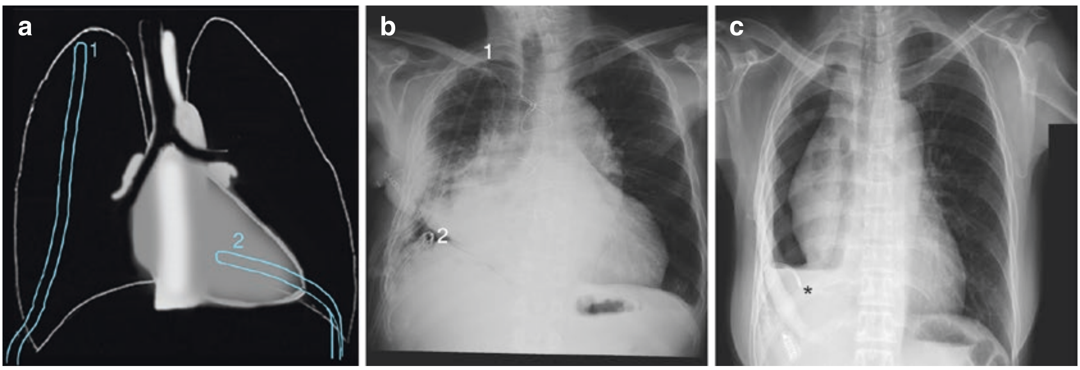

Fig. 1.17 Drainage tubes placed at lung apices (1) or at lung bases (2): schematic representation (**a**) and CXR appearance (**b**); flexible catheter at right lung base in a case of hydro-pneumothorax on CXR (**c**)

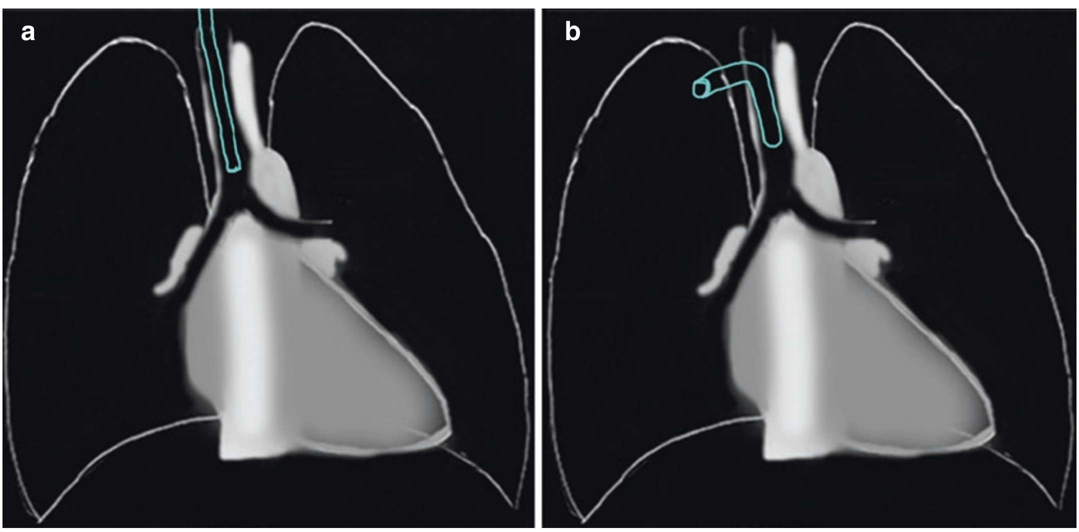

Fig. 1.18 Schematic representation of endotracheal cannula (**a**) and tracheostomy tube (**b**)

trachea, either via the oropharynx or introduced surgically through a tracheostomy; the latter method is preferred in long-period mechanical ventilation.

Tip of endotracheal cannula might be 5 cm above carina, approximatively at T4–T5 intervertebral space. Notice that sometimes a double-lumen device approach is utilized to control ventilation for each lung.

CXR is able to depict the misplacement of ET devices that often migrate to right main bronchus determining combination of overinflation and atelectasis. Other possible misplacements of ETT detectable by CXR are endo-laryngeal site, where its cuff can injure vocal cords, and intraesophageal location [24].

1.7.3 Esophageal Devices

Nasogastric (NG) catheter is employed for enteral nutrition or gastric aspiration in particular clinical conditions. CXR is rarely used for feeding tube assessment (Fig. 1.19) with the exception of unconscious patients. The lower tip of nasogastric tube should preferably be placed in the upper small bowel (distal duodenum), as assessable through abdominal X-ray [25].

1.7.4 Cardiovascular Devices

Central venous catheters may insert through either subclavian or internal jugular vein of both sides or occasionally via the femoral vein, particularly in babies. These devices have been developed to monitor central venous pressures and to safe deliver large volumes of fluids over long periods [26]. Correct placement of CVC tip is recognizable by CXR and it is considered between the most proximal venous valves of the subclavian or jugular veins and the right atrium (Fig. 1.20); if the tip of the catheter is placed inside right cardiac chambers, it may cause arrhythmias or cardiac perforation.

Other complications of CVC placement are pneumothorax (Fig. 1.21) and injury to venous walls with secondary thrombosis. Ultrasound-guided CVC positioning has permitted to significantly decrease complication rates [27].

Swan-Ganz (SG) catheters are used to monitor pulmonary capillary wedge pressure; the tip is placed in pulmonary artery when measurements are assessed. CXR may assess correct positioning of SG tip that may project within the mediastinal shadow (Fig. 1.22).

Malpositioning of Swan-Ganz catheters may occur in a quarter of the patients, resulting in

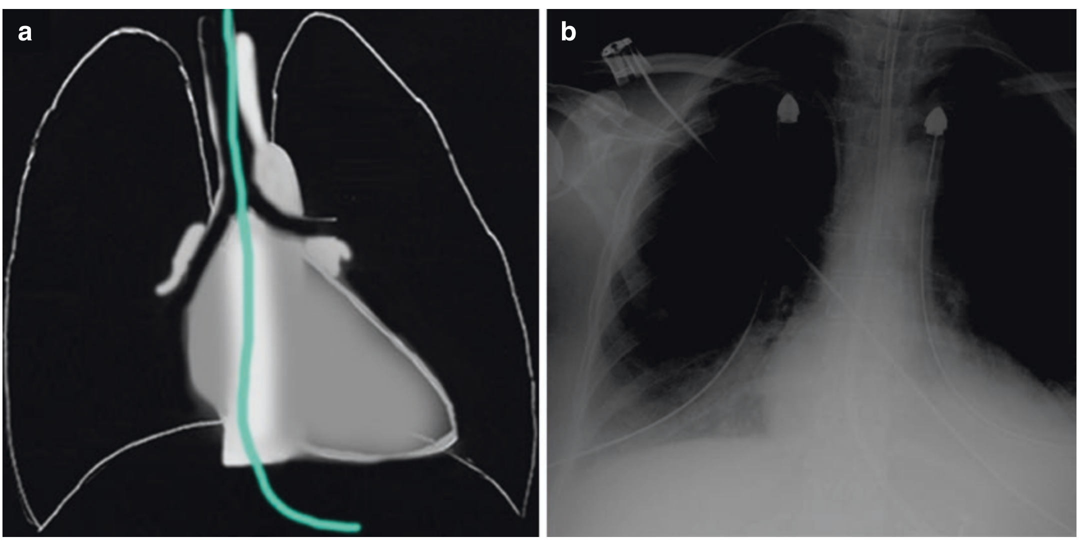

Fig. 1.19 Nasogastric catheter: schematic representation (**a**) and CXR appearance (**b**)

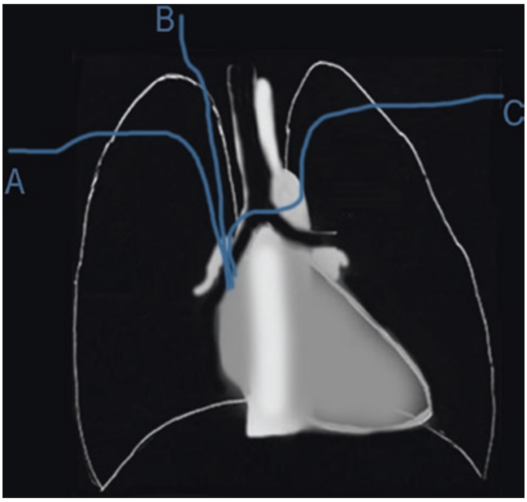

Fig. 1.20 Schematic representation of correct CVC placement

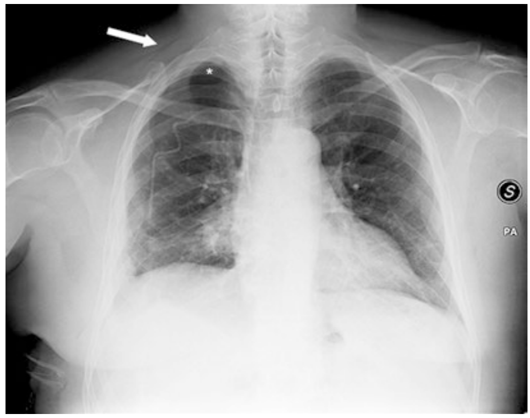

Fig. 1.21 Post CVC placement right lung pneumothorax on CXR

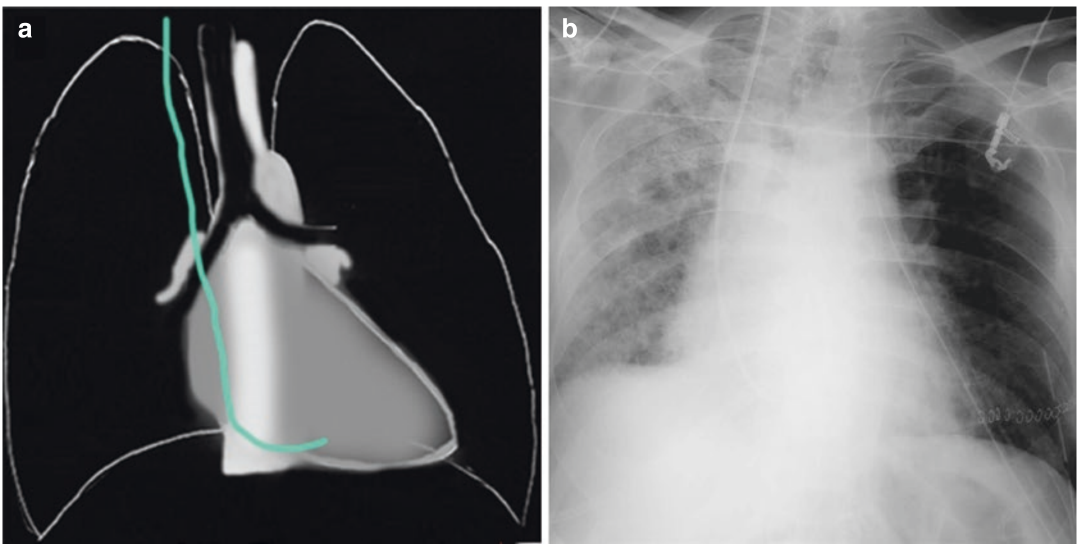

Fig. 1.22 Swan-Ganz catheter: schematic representation (**a**) and CXR appearance (**b**)

false pulmonary capillary wedge pressure readings, risk for pulmonary infarction, pulmonary artery perforation, cardiac arrhythmias, and endocarditis.

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2 Indications to the Use of Computed Tomography in Thoracic Pathologies

Francesco Lavra and Luca Saba

Abstract

During the past decades, improvement in computed tomography (CT) technology and post-processing techniques have favoured its wide use in the clinical practice.

Nowadays, CT does not only provide a mere anatomical assessment but is also capable to give information regarding the chemical composition, as well as the blood flow of the scanned tissue. The rapid coverage of large anatomic volumes and its high spatial and temporal resolution also make CT particularly suitable in the assessment of criticaly ill patients. Moreover, CT allows a detailed assessment of lung parenchyma, interstitium, and airways, as well as the thoracic vasculature and coronary arteries. Because of these technical and diagnostic characteristics CT has gained a crucial role in the assessment of thoracic pathologies.

Given the risk associated with radiation exposure and contrast media administration, it is of paramount importance to appropriately use CT in the clinical situations in which this technique has the proper diagnostic yield.

The purpose of this chapter is to explain the clinical indication of CT in thoracic pathologies to establish the appropriateness criteria for use of this technique in standard diagnostic care.

Keywords

Computed tomography · Thoracic pathology · Anatomical assessment · Neoplastic disease · Vascular disease · Lung disease

2.1 Basic Technical Principles

In the past decade, the improvement in CT scanner technologies has allowed rapid coverage of large anatomic volumes, submillimeter isotropic spatial resolution, and temporal resolution as low as 66 ms [1] with a limited requirement for sedation and anesthesia in patients unable to cooperate with a short breath hold [2, 3].

CT enables visualization of the lung parenchyma, interstitium, and airways with great anatomic details; ECG gating allows delineation of the aortic root and of coronary artery involvement minimizing imaging artifacts caused by cardiac motion [1].

A variety of post-processing techniques can be retrospectively utilized by radiologists depending on a specific clinical question [4]:

- Two-dimensional multiplanar reformations allow to visualize the acquired images in any spatial plane.

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