

CONTINUING EDUCATION PROGRAM: FOCUS...

Normal postoperative appearances of lung cancer



S. Bommart^{a,b,*}, J.P. Berthet^{b,c}, G. Durand^a,
B. Ghaye^e, J.L. Pujol^d, C. Marty-Ané^c, H. Kovacsik^a

^a Department of Radiology, Arnaud-de-Villeneuve Hospital, Montpellier University Hospitals, 371, avenue du Doyen-Gaston-Giraud, Montpellier, France

^b PhyMedExp, University of Montpellier, INSERM U1046, CNRS UMR 9214, Montpellier, France

^c Department of Thoracic Surgery, Arnaud-de-Villeneuve Hospital, Montpellier University Hospitals, 371, avenue du Doyen-Gaston-Giraud, Montpellier, France

^d Department of Thoracic Oncology, Arnaud-de-Villeneuve Hospital, Montpellier University Hospitals, 371, avenue du Doyen-Gaston-Giraud, Montpellier, France

^e Department of Radiology, St Luc University Clinic, Catholic University de Louvain, avenue Hippocrate, Brussels, Belgium

KEYWORDS

Lung cancer;
Pneumonectomy;
Lobectomy;
Thoracic surgery;
Postoperative
findings

Abstract The major lung resections are the pneumonectomies and lobectomies. The sublobar resections are segmentectomies and wedge resections. These are performed either through open surgery through a thoracotomy or by video-assisted mini-invasive surgery for lobectomies and sublobar resections. Understanding the procedures involved allows the normal postoperative appearances to be interpreted and these normal anatomical changes to be distinguished from potential postoperative complications. Surgery results in a more or less extensive physiological adaptation of the chest cavity depending on the lung volume, which has been resected. This adaptation evolves during the initial months postoperatively. Chest radiography and computed tomography can show narrowing of the intercostal spaces, a rise of the diaphragm and shift of the mediastinum on the side concerned following major resections.

© 2016 Editions françaises de radiologie. Published by Elsevier Masson SAS. All rights reserved.

The main indication for oncological thoracic surgery is currently non-small cell lung cancer (NSCLC). Lobectomies and pneumonectomies are the major scheduled lung resections and follow the principles of radical oncological surgery. These are combined with routine ipsilateral mediastinal lymph node dissection [1,2]. These procedures may be extended to include neighboring structures aiming always to achieve a resection margin passing through

* Corresponding author. Department of Radiology, Arnaud-de-Villeneuve Hospital, Montpellier University Hospitals, 371, avenue du Doyen-Gaston-Giraud, Montpellier, France.

E-mail address: s-bommart@chu-montpellier.fr (S. Bommart).

healthy tissue. Sublobar resections, segmentectomies, or *wedge resection* may be carried out in selected cases [3].

These different resection procedures result in anatomical changes in the chest, which evolve over time. Interpretation of postoperative imaging for lung cancer should therefore make it possible to distinguish normal anatomical changes from those due to complications.

We have examined the postoperative follow-up appearances of major and sublobar lung resections and, to distinguish the early and late radiological findings (chest radiography and computed tomography [CT]).

Specific features of thoracic oncological surgery

Radical surgery remains the reference curative treatment for localized NSCLC (stages 1 and 2), either in isolation or as part of multimodal treatment [1,2]. The extent of the resection depends on T status, the site of the lesion and pulmonary function. Resection is carried out by dividing and suturing arterial and venous components and the bronchial pedicle for scheduled surgery (pneumonectomy, lobectomy and segmentectomy) – or extra-anatomically for unscheduled surgery (wedgeresection).

Since the prospective *Lung Cancer Study Group* study in 1995 which described 3 and 5 times more recurrences after anatomical segmentectomy or wedge resection respectively [4], lobectomy/lymph node dissection has been the standard procedure for localized NSCLC.

Pneumonectomy is indicated for central, bulky or multifocal tumors and is classically intrapleural, removing the lung and its visceral pleura. The extrapleural procedure is reserved for NSCLC with extension to the parietal pleura or for primary pleural tumors. Pneumonectomy, particularly on the right side, is associated with high morbidity and mortality [5], a significant reduction in quality of life, as well as limited treatment options if the tumor recurs.

These pitfalls can be reduced by a number of parenchymal-sparing techniques, which preserve the oncological quality of the procedure provided they are combined with extemporaneous examination of the resection specimens. These involve particularly sleeve lobectomies, which

are carried out if the tumor has extended to the bronchial tree or pulmonary arterial system (Fig. 1) [6].

Radical resection may then need extension to the chest wall (ribs, vertebrae, and diaphragm), the major vessels (pulmonary artery trunk, pericardium, superior vena cava) or the atria [7].

Sublobar parenchymal resections can be offered for non-invasive or only minimally-invasive lesions such as atypical adenomatous hyperplasia, *in situ* adenocarcinoma or micro-invasive adenocarcinoma, or in patients with marginal pulmonary function [8,9].

“Mini-invasive” surgery is tending to take over from conventional surgery with thoracotomy in selected situations, particularly stage T1 NSCLC for which lobectomy is indicated [10]. This technique was first developed in the 1990s and involves the same resection procedure as conventional surgery, although it uses only video-assisted thoracoscopy (Fig. 2). The aim of video-assisted surgery is to reduce postoperative pain due to intercostal spacing, as well as the risk for complications which may arise from this such as atelectasis or pneumonia, in order to shorten hospital stays and enable patients to resume their usual activities more quickly [11,12]. Although pneumonectomy can theoretically be performed using the same approach, mini-invasive surgery is still mostly reserved for atypical resections and lobectomies suitable for this approach on presentation. Robotics have been introduced in recent years and may now be used to assist these procedures [13].

The inherent principle of thoracoscopy precludes manual palpation for nodules. Perioperative identification can therefore be difficult, and preoperative identification is used by CT guided implantation of landmarks (coils or harpoons) to map out the target lesion (Fig. 3) [14].

Normal postoperative appearances

Chest radiography

During the hospital stay

Lobectomies and sublobar resections

A standard chest film is sufficient in the immediate follow-up period after lung resections in patients who have a normal

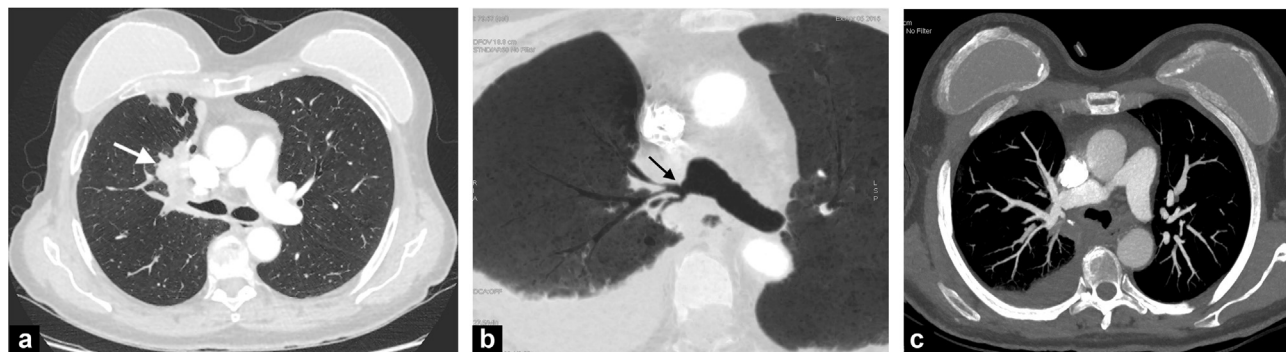


Figure 1. A 58-year-old patient treated for right upper lobe adenocarcinoma with extension to the main bronchus (arrow). Preoperative axial CT image in the parenchymal window after IV contrast enhancement (a). This image shows central tumor infiltration extending to the right main bronchus. Postoperative axial CT image with iodine contrast enhancement. Min IP axial reconstruction shows reinsertion of the right lower lobe bronchus into the main bronchus (b) (arrow). The MIP reconstruction shows the end to end anastomosis and interposition of a vascular graft (c). The tissue density image behind the allograft represents the presence of an intercostal flap.

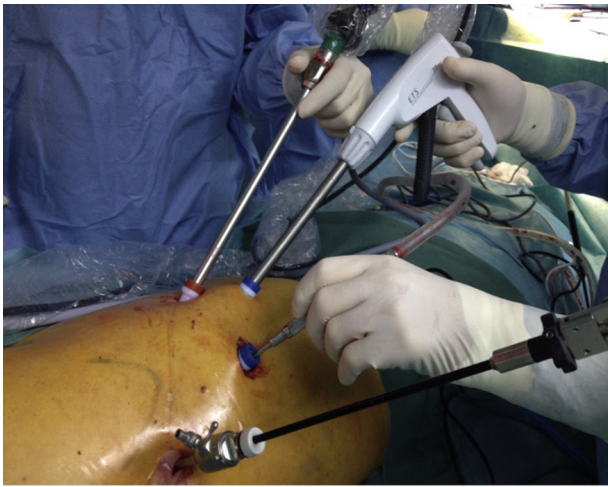


Figure 2. Positioning of trocars for video-assisted lobectomy.

uncomplicated postoperative course. This is performed initially in the semi-seated position and then shortly afterwards with the patient standing and chest tubesset to aspiration or to siphon mode. These films are taken at least during the

postoperative check, after removing drains, and before the patient is discharged.

Several findings can be observed in the initial phase, depending on the type of surgery. The position of the chest tube should be reported, together with any central venous access present in the early postoperative phase. A postero-basal drain is usually inserted in order to remove liquid effusions and an antero-apical drain to remove air. Dual drainage can be replaced by a longer drain fulfilling both functions (Figs. 4 and 5). A pneumothorax is not always present. If the lung does not reach the chest wall, the chest film can guide the clinician in terms of adjusting drain aspiration or changing the drain if it continues to return air (> 7 days). Prolonged air bubbling through the drain is usually due to an unpatched air leak but can occasionally be explained by defective contents/container adaptation. This re-expansion defect is often associated with underlying parenchymal damage, either due to COPD or a history of previous irradiation (Fig. 6).

The presence of subcutaneous emphysema is not always pathological. This is revealed by dissection of the chest and often cervical muscle and adipose tissues by air and may occasionally be associated with a pneumomediastinum. These morphological abnormalities should therefore be reported and reassessed during follow-up.

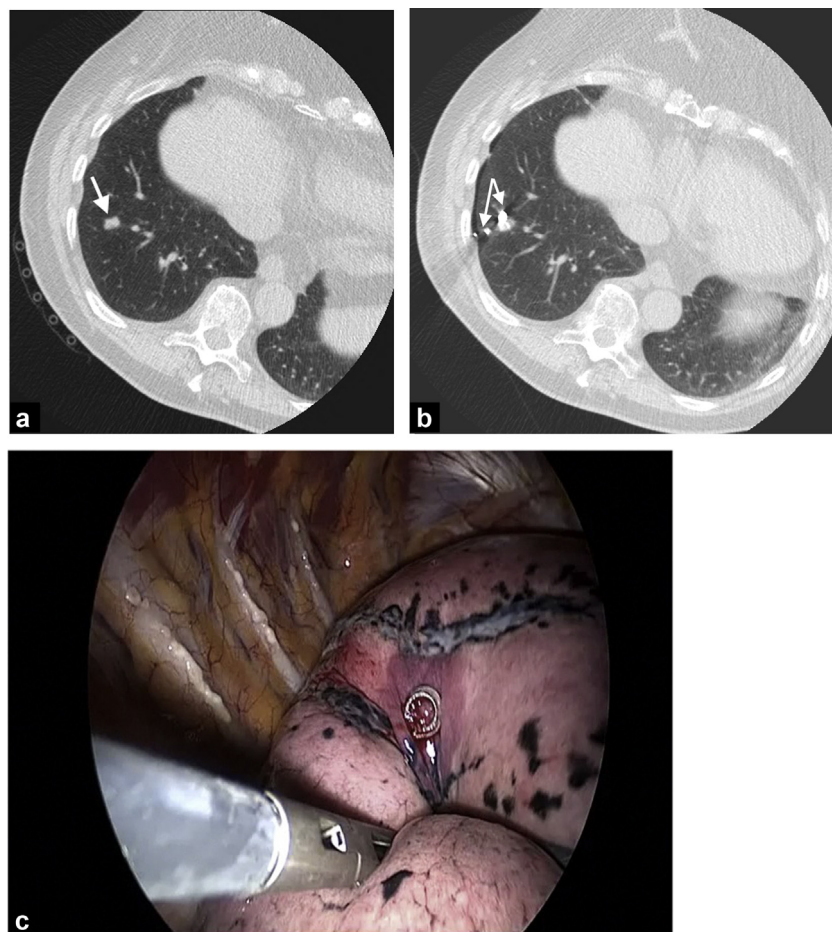


Figure 3. A centimeter-sized tissue nodule (arrows) found in a 72 year old female patient. Axial CT image in the parenchymal window before (a) and after (b) insertion of coils. Thoracoscopic view of pleural expression of the coil appearing as a spiral shaped metal image combined with the pleural hematoma (c).

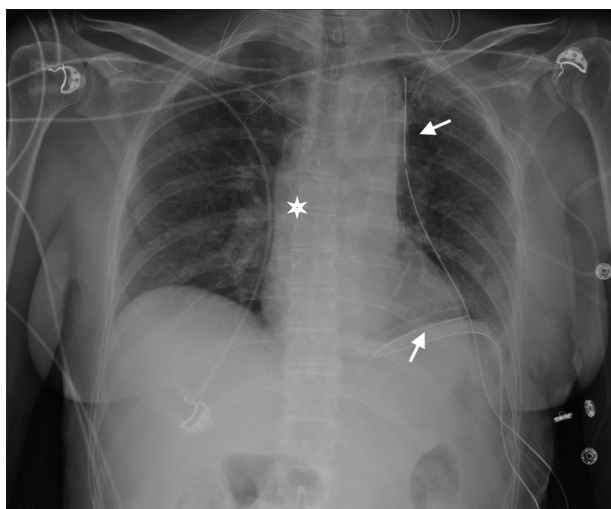


Figure 4. Postoperative postero-anterior chest film in a 65-year-old male patient treated for left upper lobe adenocarcinoma. This image shows an apical pleural drain and a second basal drain (arrows). There is also a PICC line in situ, the end of which is situated next to the superior vena cava.

Postoperative atelectasis is common and may be sub-segmental, segmental, or proximal either on the surgical side or in the contralateral lung field. Imaging shows retractile parenchymal opacification with a peripheral base and with its apex at the hilum combined with displacement of the fissure and attraction of neighboring structures. It is important to look for signs of mediastinal retraction in patients with a unilateral complete hemithorax white out in order to distinguish atelectasis from a pleural effusion.

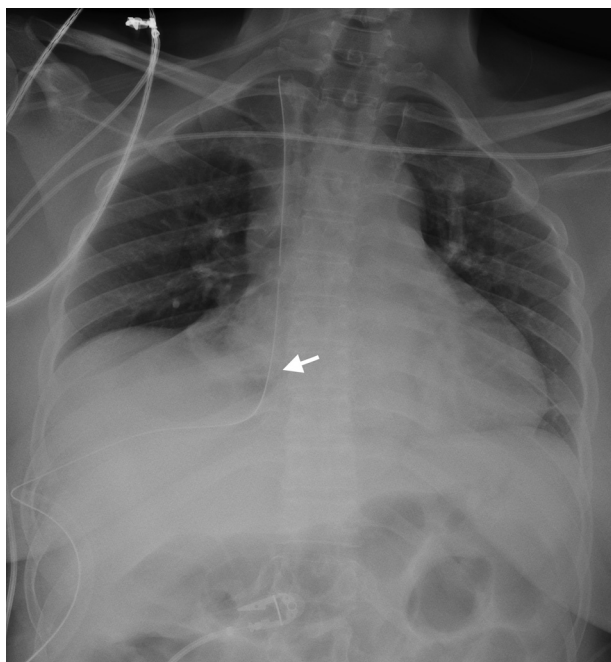


Figure 5. Chest film after resection of the right basal pyramid for micro-invasive adenocarcinoma in a 43-year-old female patient. This film shows a single drain (arrow) extending from the base to the apex.

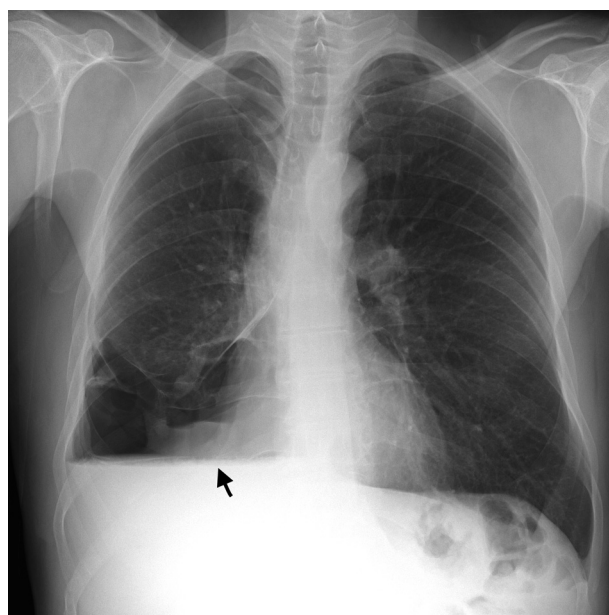


Figure 6. Postero-anterior chest film performed 1 month after inferior and middle lobe bi-lobectomy for a pT3 N2 M0 adenocarcinoma. The film shows a hydropneumothorax (arrow) in the right base due to defective re-expansion of the residual parenchyma. The patient underwent revision surgery for pneumatosis.

Atelectasis can be cured more easily with pain control and physiotherapy to facilitate effective coughing. It occasionally requires non-invasive ventilation or even bronchoscopy (Fig. 7). Extensions to the chest wall or spine treated by en bloc resection can be identified by their concomitant bony defects (Fig. 8).

Pneumonectomy

Drainage is not always used after pneumonectomy and if the remaining chest cavity is drained, a chest tube is never used in aspiration mode. During the immediate postoperative period, the pneumonectomy cavity fills with air; over time increasing amounts of fluid appear (Fig. 9) [15]. The rapid rise in fluid content is explained by reduced resorption due to the loss of the parietal pleura. Fluid level may occasionally be seen.

Minimal contralateral alveolar changes may be seen. These resolve and are due to increased flow in the contralateral lung. Acute respiratory distress syndrome (ARDS) should be considered if this sign increases.

At 1 month

Lobectomy and sublobar resection

The chest film 1 month after surgery is often performed at the time of the postoperative follow-up consultation. The aim of this film is firstly to identify the physiological adaptation of the chest cavity to loss of lung volume [16], and secondly to investigate airway obstruction signs or a residual effusion.

The loss of volume in the hemithorax concerned causes a rise in the diaphragmatic, mediastinal attraction and intercostal narrowing (Fig. 10); this is greater with inferior lobectomies and less pronounced with middle lobectomies.

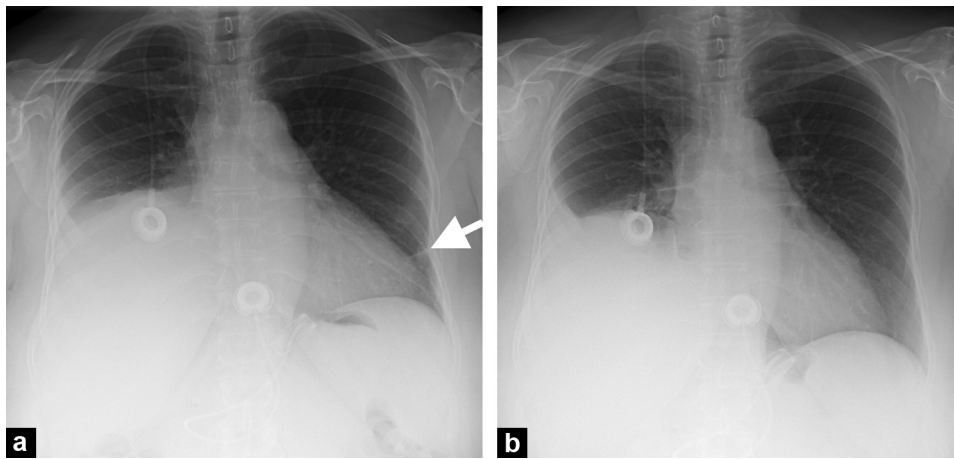


Figure 7. Postero-anterior chest film in a 56-year-old female patient on day 5 after right lower lobectomy. The film shows a contralateral band of atelectasis (arrow) (a) resolving after respiratory physiotherapy on the film taken at 1 month (b). Note also a pronounced rise in the right hemidiaphragm due to phrenic nerve paralysis.

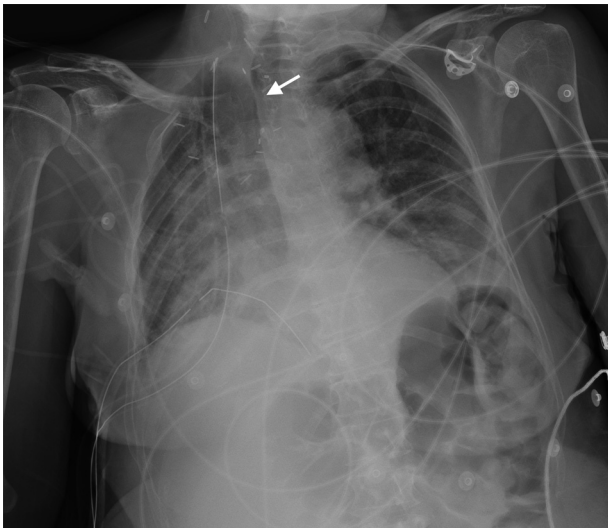


Figure 8. Postoperative postero-anterior chest film in a 69-year-old female patient after right upper lobectomy extending to the chest wall and partial resection of the vertebral bodies of T2 to T4 for a Pancoast syndrome.

The appearance of the residual parenchyma also changes with greater radiolucency on the surgical side and reduced hilar volume. A small linear opacification rising vertically from the diaphragm is seen quite often with, particularly right, upper lobectomies (Fig. 10) [17].

Pneumonectomy

The pneumonectomy cavity fills with fluid over a few weeks or months postoperatively. At the same time, the hemithorax retracts and the ipsilateral hemidiaphragm rises, combined with intercostal narrowing, and attraction of the trachea and mediastinum to the surgical side. Patients should be investigated for the complication of a bronchial fistula if the tracheal radiolucency returns to a central position [18].

Anterior transmediastinal lung herniation occurs, occasionally producing misleading appearances of residual parenchyma on a standard postero-anterior film, particularly in younger patients [15].

Computed tomography

If no clinical or radiological signs of complications are present, a CT scan with iodinated contrast media should only be performed 3 months after the procedure to obtain a morphological reference image for oncological follow-up as many normal postoperative appearances can mimic local recurrence (Fig. 11) [19].

Lobectomy and sublobar resection

The resected lobe is recognized from multiplanar reconstructions, identifying clips and bronchial and vascular stumps. The angulation of the lobar bronchus or bronchi, on the surgical side is changed (Fig. 12) [20]. A small area of tissue density may be seen around the bronchial suture and reflects localized fibrosis, the extent of which may occasionally cause a diagnostic problem. Overinflation of the residual parenchyma, mediastinal displacement, and wall retraction vary depending on the lung volume resected.

No residual fissure remains after left lobectomy or right bi-lobectomy whereas if a single lobe is resected on the right side, the fissure is displaced. It is orientated frontally with upper lobectomy, obliquely inferiorly and anteriorly with middle lobectomy and more sagittally, descending towards the back of the horizontal scissure, with inferior lobectomy. A staple line may be present if the fissure is incomplete. This is applied in order to reduce air leakages.

The CT appearances of segmentectomy or wedge resection are those of minimal parenchymal changes appearing as a peripheral linear increased density due to suture materials (Fig. 13). These appearances may be combined with a small area of reduced density reflecting atelectasis in contact with the stapled area. Segmentectomy is identified on CT by counting the bronchi. One to 4 segments may be resected. Proximal clips can be seen when

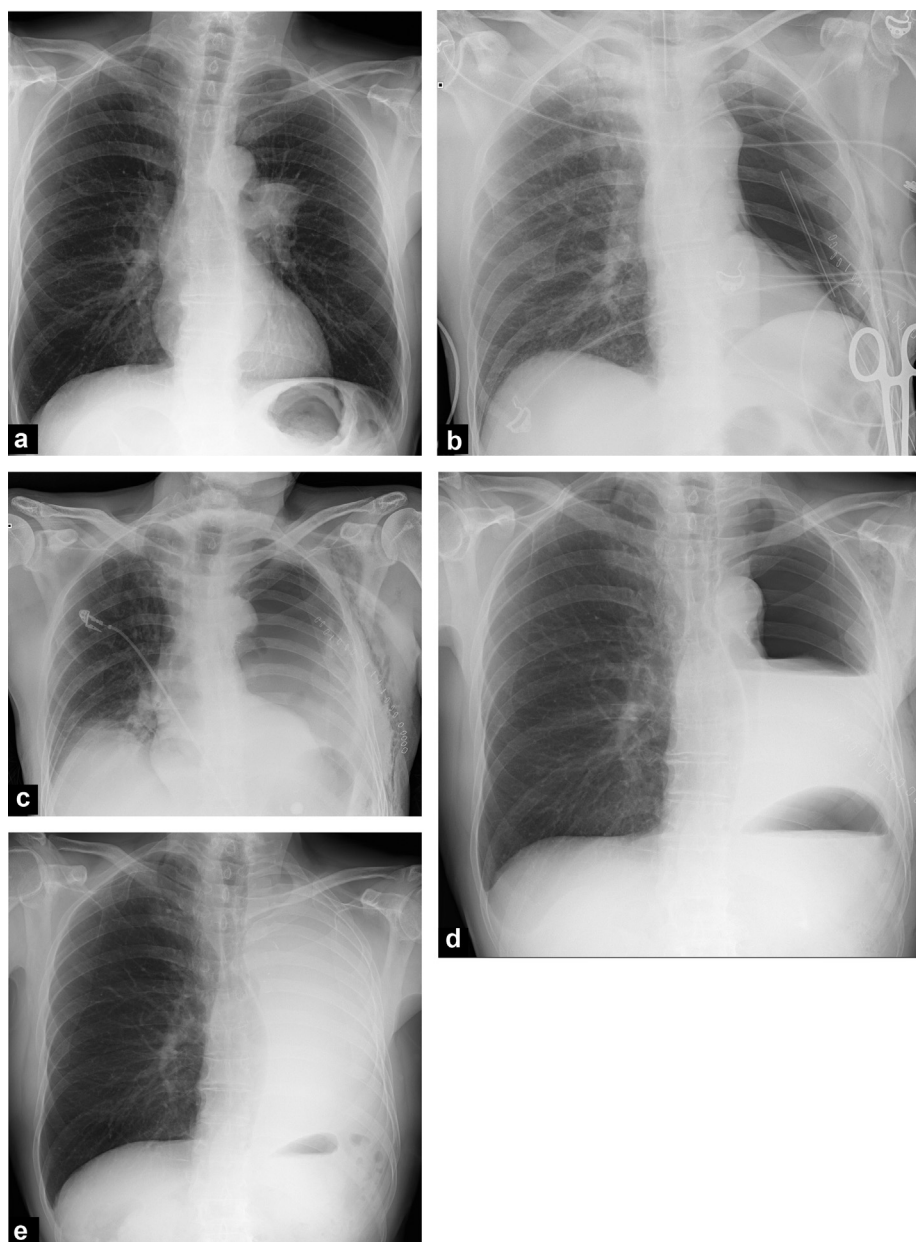


Figure 9. A 76-year-old man treated for pT2b N0 M0 squamous cell carcinoma. The postero-anterior chest film before surgery (a) shows the central tumor. An immediate postoperative film with the patient lying on his back (intubated) shows translucency of the left lung field and a drain present. The mediastinum is central (b). The film taken at 48 hours, again with the patient lying on his back, shows development of an opacification due to a liquid effusion combined with moderate subcutaneous emphysema. The drain has been removed (c). The day 7 film was performed with the patient standing up and shows a fluid-air level in the left pneumonectomy cavity and a moderate rise in the left hemidiaphragm (d). The mediastinum is deviated towards the surgical side. A standing film at 1 month shows complete liquid filling of the left pneumonectomy cavity (e).

the lobar bronchus is intact. The loss of lung volume varies, particularly with basal pyramid segmentectomy. In a wedge resection, the primary or segmental bronchi are spared.

Pneumonectomy

At three months, the CT scan shows a pneumonectomy cavity with a liquid or air-fluid level content. The parietal pleura is

enhanced with iodine. This should be regular and may vary in thickness. A nodular appearance is invariably suspicious of local recurrence.

A long bronchial stump can also pose a diagnostic problem when secretions accumulate, to distinguish from local recurrence.

Gradually, the pneumonectomy cavity retracts and calcifications may be seen in old resections (Fig. 14).

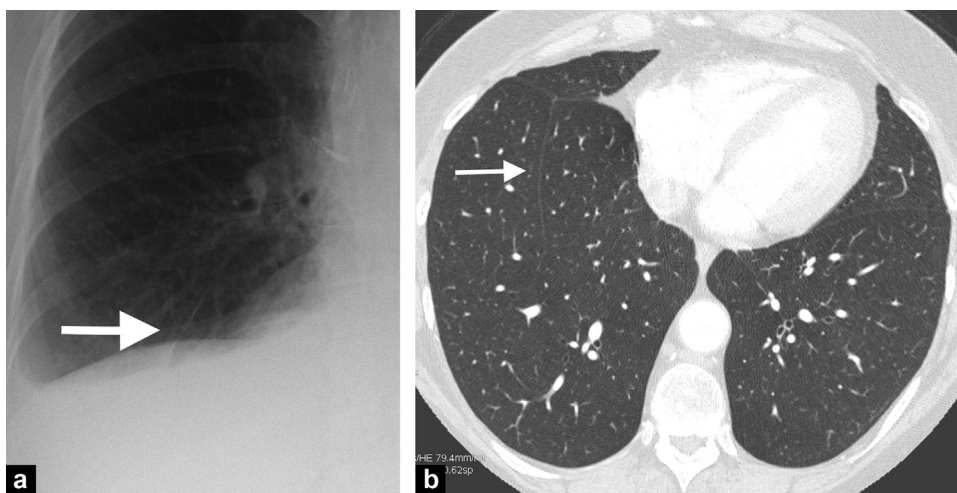


Figure 10. A 60-year-old woman treated by right upper lobectomy for a pT1 N0 M0 adenocarcinoma. The postero-anterior chest film (a) shows a supradiaphragmatic line representing a juxtaphrenic peak (arrow). Corresponding axial CT appearance in the parenchymal window (b).



Figure 11. Axial CT image in the mediastinal window after iodine enhancement in a 79-year-old male patient treated surgically for a pT2b N2 M0 squamous cell carcinoma. The image shows non-progressive tissue thickening (arrow) in contact with the left pulmonary artery.

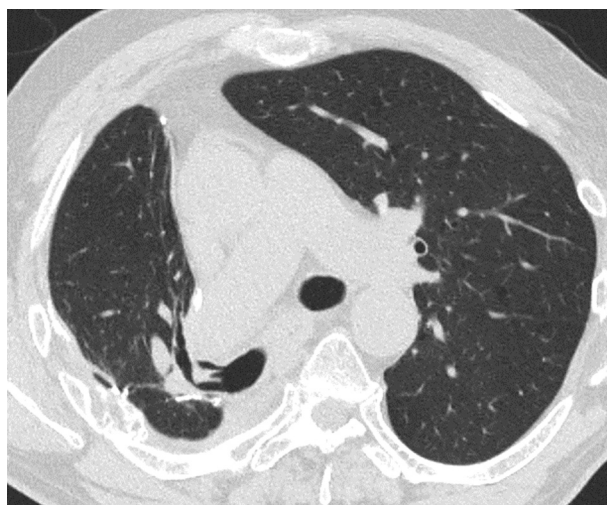


Figure 12. Axial CT image in the parenchymal window in a 59-year-old male patient treated surgically by upper lobectomy and S6 right segmentectomy for a multifocal pT4 N0 M0 adenocarcinoma. The image shows distortion of the emergence of the middle lobe bronchus and right lower lobe bronchus, narrowing of the intercostal spaces and a retrohilar staple line can also be seen. Note the increased density images in the pleural space due to apposition of hemostatic materials applied during revision surgery for clot removal on d15 postoperatively.



Figure 13. Axial CT image in the parenchymal window in a 64-year-old male patient treated surgically for an in situ adenocarcinoma. The image shows a linear increased density due to a parenchymal staple line.

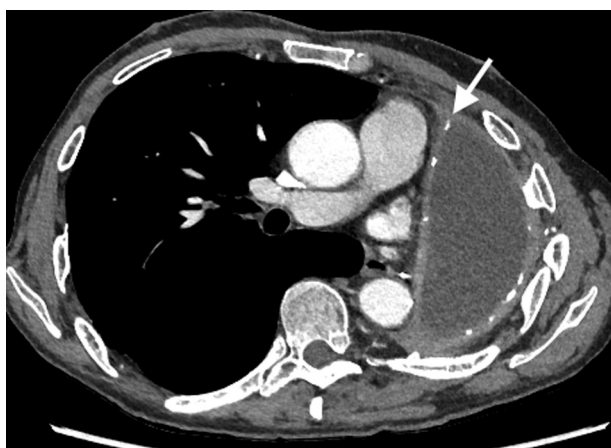


Figure 14. Axial CT image in the mediastinal window after contrast enhancement in a 45-year-old man treated surgically by pneumonectomy 8 years ago for a pT3 N0 M0 upper lobe adenocarcinoma. The image shows a retracted left pneumonectomy cavity, the walls of which appear to be partially calcified (arrow).

Conclusion

The structural changes in the chest, which occur as a result of lung resection surgery are explained by the type of procedure performed. Knowledge of the normal changes in the chest film is essential in order to be able to identify postoperative complications.

The reduction in length of hospital stay to 24 h or 48 h after surgery in very highly selected patients (those with a complete scissure, no emphysema, localized excision or lobectomy) make interpretation of the chest film even more essential in order to enable early discharge.

Take-home messages

- A standard chest radiograph is sufficient for follow-up in the immediate postoperative period in patients who have a normal uncomplicated postoperative course.
- A CT at three months after lung parenchymal resection surgery is used to assess the structural changes in the chest and obtain a reference image for oncological follow-up.
- It is important to look for signs of mediastinal retraction in patients with a unilateral white lung in order to distinguish atelectasis from a pleural effusion.
- A vertical linear opacification arising from the diaphragm, known as the juxtaphrenic peak, may be seen on the chest film after upper lobectomy.

Clinical case

A 68-year-old patient was referred to thoracic surgery outpatients for a suspicious right upper lobe nodule found on a CT performed because of chest pain.

The patient's main past history was ischemic heart disease with stenting, drug-induced pancreatitis, COPD, and smoking (stopped 3 months previously).

On the CT, the nodule appeared as a polylobulated centimeter-sized tissue structure next to the ventral segment of the right upper lobe (Fig. 15). No hilar or mediastinal lymphadenopathy was seen. On PET CT, the lesion showed increased glucose metabolism and the patient had no other thoracic or extra-thoracic uptake.

The decision was taken in a multidisciplinary team meeting to carry out video-assisted thoracoscopic lobectomy, which was performed in October 2014. Histology showed a pT1b N0 M0 adenocarcinoma. The patient underwent revision surgery for significant air bubbling in the drain on waking. His chest film showed persistent pneumothorax (Fig. 16) and peroperative examination revealed an area bubbling in the posterior part of the greater scissure in an extremely dystrophic region, which was treated by application of a hemostatic sponge and biological glue.

A repeat CT at 1 month showed pseudothickening of the fissure with a liquid density (Fig. 17), which had been replaced by a partially aerated serpiginous appearance still located in the posterior part of the scissure (Fig. 18). This had filled again on a further CT performed 18 months after surgery (Fig. 19).

Questions

1. What are the predictive preoperative factors for aerostatic difficulties in this patient?
2. Is revision surgery indicated on the basis of the pneumothorax on the postoperative film?
3. How do you explain the fluctuating postoperative image next to the resection scar on the CT?

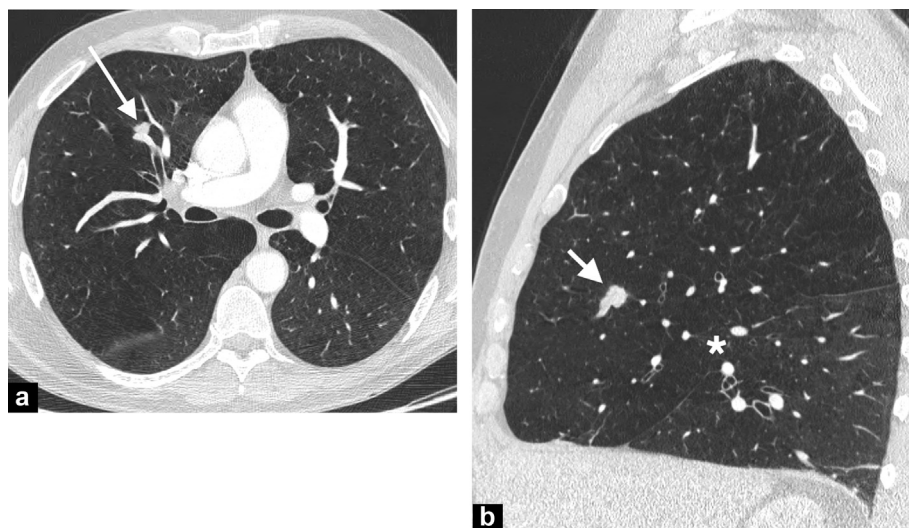


Figure 15. Axial CT image in the parenchymal window (a) and sagittal reconstruction (b). The images show a polylobulated tissue nodule, which has developed in emphysematous parenchyma. Note the incomplete scissure, which is clearly visible on the sagittal reconstruction.

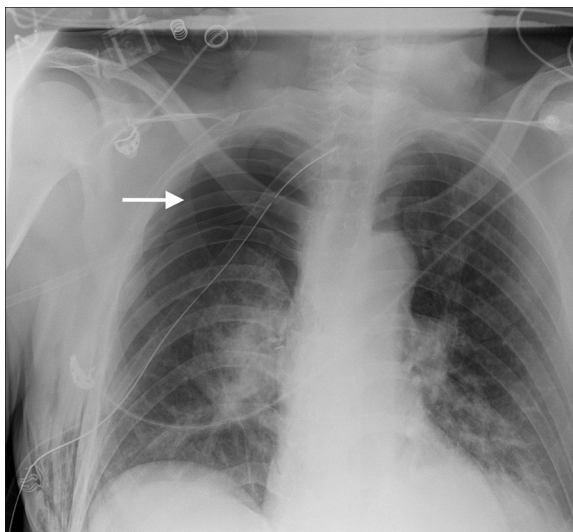


Figure 16. Standard postero-anterior chest film taken in the immediate postoperative period. The image shows a pneumothorax despite the pleural drain in situ. Note the moderate subcutaneous emphysema close to the pleural drain insertion site and slight deviation of the trachea towards the surgical side.



Figure 17. Follow-up CT image in the parenchymal window 3 months after right upper lobectomy. The image shows asymmetrical lung fields with reduced volume on the right. It also shows vertical displacement the scissure with right posterior pseudothickening of the scissure due to a small partitioned effusion.



Figure 18. Follow-up CT image in the parenchymal window 1 year after surgery. This shows regression of the liquid effusion, which has been replaced by a partially aerated serpiginous appearance.

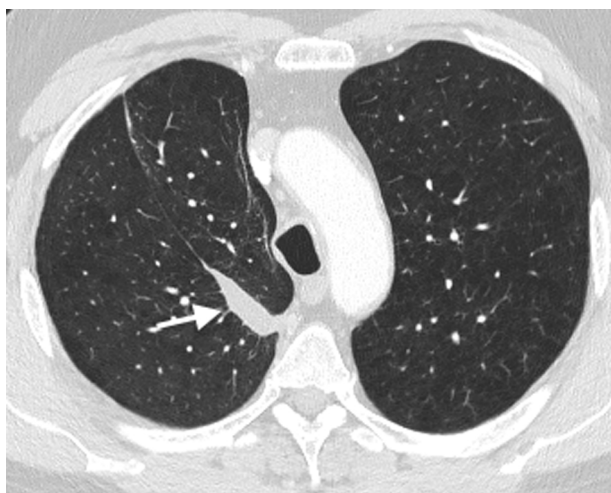


Figure 19. Follow-up CT image in the parenchymal window 18 months after surgery. This image shows recurrence of the minimal partitioned effusion in the resection scar.

Answers

1. Emphysema and an incomplete fissure are two factors, which can be seen on the preoperative CT which predispose to aerostatic difficulties in chest surgery.

2. The findings on the postoperative chest film alone do not represent an indication for revision surgery, although they do if they are associated with extensive persistent air bubbling.

3. The anatomical changes such as those seen next to the scissure can be understood from knowledge of the specific surgical procedure. The appearances seen on the repeat CT at 1 year may be explained by the surgical materials used in the revision surgery and fibrinous changes. Hemostatic materials may occasionally appear as increased densities on an unenhanced view and make the image difficult to interpret. These are occasionally incorrectly interpreted as a recurrence or a textiloma.

Disclosure of interest

The authors declare that they have no competing interest.

References

- [1] Detterbeck FC, Lewis SZ, Diekemper R, Addrizzo-Harris D, Alberts WM. Diagnosis and management of lung cancer, 3rd ed: American college of chest physicians evidence-based clinical practice guidelines. *Chest* 2013;143:75–375.
- [2] Lederlin M, Revel MP, Khalil A, Ferretti G, Milleron B, Laurent F. Management strategy of pulmonary nodule in 2013. *Diagn Interv Imaging* 2013;94:1081–94.
- [3] Baltayiannis N, Chandrinos M, Anagnostopoulos D, Zarogoulidis P, Tsakiridis K, Mpaka, et al. A lung cancer surgery: an up to date. *J Thorac Dis* 2013;5:425–39.
- [4] Ginsberg RJ, Rubinstein LV. Randomized trial of lobectomy versus limited resection for T1 N0 non-small cell lung cancer. Lung Cancer Study Group. *Ann Thorac Surg* 1995;60:615–22.
- [5] Pricopi C, Mordant P, Rivera C, Arame A, Foucault C, Dujon A, et al. Postoperative morbidity and mortality after pneumonectomy: a 30-year experience of 2064 consecutive patients. *Interact Cardiovasc Thorac Surg* 2015;20:316–21.
- [6] Berthet JP, Paradela M, Jimenez MJ, Molins L, Gómez-Caro A. Extended sleeve lobectomy: one more step toward avoiding pneumonectomy in centrally located lung cancer. *Ann Thorac Surg* 2013;96:1988–97.
- [7] Speicher PJ, Englum BR, Ganapathi AM, Onaitis MW, D'Amico TA, Berry MF. Outcomes after treatment of 17,378 patients with locally advanced (T3N0-2) non-small-cell lung cancer. *Eur J Cardiothorac Surg* 2015;47:636–41.
- [8] Cho JH, Choi YS, Kim J, Kim HK, Zo JI, Shim YM. Long-term outcomes of wedge resection for pulmonary ground-glass opacity nodules. *Ann Thorac Surg* 2015;99:218–22.
- [9] Altorki NK, Yip R, Hanaoka T, Bauer T, Aye R, Kohman L, et al. Sublobar resection is equivalent to lobectomy for clinical stage 1A lung cancer in solid nodules. *J Thorac Cardiovasc Surg* 2014;147:754–62.
- [10] Flores RM, Park BJ, Dycoco J, Aronova A, Hirth Y, Rizk NP, et al. Lobectomy by video-assisted thoracic surgery (VATS) versus thoracotomy for lung cancer. *J Thorac Cardiovasc Surg* 2009;138:11–8.
- [11] Nwogu CE, D'Cunha J, Pang H, Gu L, Wang X, Richards WG, et al. VATS lobectomy has better perioperative outcomes than open lobectomy: CALGB 31001, an ancillary analysis of CALGB 140202 (Alliance). *Ann Thorac Surg* 2015;99:399–405.
- [12] Andreotti C, Menna C, Ibrahim M, Ciccone AM, D'Andrilli A, Venuta F, et al. Postoperative pain control: videothoracoscopic versus conservative mini-thoracotomy approach. *Eur J Cardiothorac Surg* 2014;46:907–12.
- [13] Gharagozloo F, Margolis M, Tempesta B. Robot-assisted thoracoscopic lobectomy for early-stage lung cancer. *Ann Thorac Surg* 2008;85:1880–5.
- [14] Bommart S, Bourdin A, Marin G, Berthet JP, Pujol JL, Serre I, et al. Impact of preoperative marking coils on surgical and pathologic management of impalpable lung nodules. *Ann Thorac Surg* 2014;97:414–8.
- [15] Padovani B, Ducreux D, Macario S, Maillard M, Iannessi A, Brunner P, et al. Imagerie du thorax post-opératoire : les aspects normaux. *J Radiol* 2009;90:991–1000.
- [16] Kim CW, Godelman A, Jain VR, Merav A, Haramati LB. Post-lobectomy chest radiographic changes: a quantitative analysis. *Can Assoc Radiol J* 2011;62:280–7.
- [17] Konen E, Rozenman J, Simansky DA, Yellin A, Greenberg I, Konen O, et al. Prevalence of the juxtaphrenic peak after upper lobectomy. *AJR Am J Roentgenol* 2001;177:869–73.

- [18] Bommart S, Berthet JP, Durand G, Pujol JL, Mathieu C, Marty-Ané C, et al. Imaging of postoperative complications following surgery for lung cancer. *Diagn Interv Imaging* 2015, <http://dx.doi.org/10.1016/j.diii.2015.06.022>.
- [19] Alpert JB, Godoy MC, Degroot PM, Truong MT, Ko JP. Imaging the post-thoracotomy patient anatomic changes and postoperative complications. *Radiol Clin North Am* 2014;52: 85–103.
- [20] Seok Y, Cho S, Lee JY, Yang HC, Kim K, Jheon S. The effect of postoperative change in bronchial angle on postoperative pulmonary function after upper lobectomy in lung cancer patients. *Interact Cardiovasc Thorac Surg* 2014;18:183–8.