



REVIEW / *Thoracic imaging*

Imaging of postoperative complications following surgery for lung cancer

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Abstract The complications following surgery for lung cancer vary depending upon the comorbidities and the type of surgery. Hemorrhage, infections and pulmonary edemas are not specific to the type of resection but frequently occur following pneumonectomies. Morbidity following pneumonectomies is related to the significant changes in the contents of the intrathoracic space. Pulmonary infarction and torsion are emergency situations that develop following lobectomy. CT shows features of localized congestion and stenosis or occlusion of a vein or bronchus. Rapid identification of severe events, in particular by systematic CT is essential for appropriate management of a postoperative or delayed complication of lung cancer surgery.

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Recent epidemiological data from the National Cancer Institute (Institut national du cancer [INCa]) show that lung cancer is still a frequent clinical problem with a poor clinical prognosis. It is the fourth most frequent cancer and the first cause of cancer death in France [1].

Despite the recent progress of targeted therapies or immunotherapy, surgery is still the first line treatment option for both early and more advanced forms of non-small-cell lung cancer (NSCLC) [2].

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The extent of resection mainly depends upon locoregional invasion and should fulfill oncological and functional criteria. In the early stages surgical treatment involves anatomical resection of one lobe (lobectomy). Extension of resection to the entire lung (pneumonectomy), or a second lobe (bilobectomy) on the right is indicated in the presence of tumoral invasion of the arteries, veins, bronchi or proximal or central parenchyma. Parenchymal-sparing resection is a validated alternative for pneumonectomies [3]. It is proposed to preserve pulmonary respiratory and vascular function. These include bronchial and bronchovascular sleeve resections [4].

In the presence of locally advanced NSCLC cancer (pT3 or pT4) resection is extended to surrounding structures (pleura, chest wall, vertebral bodies, diaphragm, mediastinal structures such as the pericardium, auricles, trachea, thoracic aorta or superior vena cava, etc.) In these cases the surgical procedure may be more difficult and require a multidisciplinary surgical team for resection and reconstruction of these structures.

Although the mortality rate is generally low (<1%) for very limited resections, it increases for lobectomies (between 1.2 and 4%) and can reach 6% for pneumectomies [5,6]. Mortality is secondary to complications from surgery which occur in between 24 and 41% of cases, depending on the difficulty of the procedure and comorbidities [7,8].

Imaging plays an important role in the postoperative follow-up and diagnosis of the complications of surgery for lung cancer. Standard X-ray is the reference imaging technique, and is sufficient in case of normal follow-up. In case of complications it is often insufficient, and CT scan is the main technique for the initial evaluation of postoperative complications and follow-up of patients. Postoperative anatomical changes and the lack of specificity of certain features such as alveolar condensation make it necessary to systematically analyze the pulmonary parenchyma, pleura and vascular connections while taking into account the surgical procedure and symptoms.

Imaging acquisition protocol

CT of the complications of surgery for lung cancer is obtained following intravenous administration of an iodinated contrast agent to confirm the permeability of vascular structures. The maximum intensity projection (MIP) mode allows easy identification of any arterial or venous pulmonary obstruction. Contrast enhancement also identifies fluid collections, recurrence or embolic complications.

The min IP mode (minimum intensity projection) is a diagnostic tool to determine bronchial complications such as stenosis or torsion.

Normally, low effective dose protocols are preferable [9–11].

General complications

Postoperative hemorrhage

Postoperative hemorrhage is an early complication. It is rare (between 0.1–3%) and rarely fatal (1%) [12]. It presents with

signs of hemodynamic collapse and compression. The diagnosis is easy in the presence of a decrease in red blood cells in the first postoperative hours severe hemorrhage with collapse does not require any other imaging test, and rapid revision surgery is indicated.

When the hemorrhage is more latent, it is associated with the development of a clot that cannot be evacuated by the chest tube insertion draining. CT shows a dense, sometimes heterogeneous pleural fluid collection which may have the features of a pseudotumor later on. The presence of the mediastinal shift, which is a sign of compression, should be looked for. Even if evidence of extravasation is rare on CT (Fig. 1), it should be looked for. A pseudoaneurysm of the pulmonary artery due to dehiscence of the vascular suture may be identified (Fig. 2). This must be identified due to the risk of secondary rupture and hemorrhagic shock [13].

Pulmonary edema

The frequency of this complication is estimated to be between 2.5 and 5% for pneumonectomy [14,15]. There are secondary forms that are cardiogenic, thromboembolic or associated with infection. The primary or idiopathic form is multifactorial. It is the result of a combination of physiopathological elements associated with lung ventilation (hyperoxia, (hyperoxia and pulmonary baro- and volutrauma) and elements associated with increased blood flow in the in the remaining pulmonary artery [16]. In the absence of appropriate and rapid management, this can progress to an acute respiratory distress syndrome (ARDS), which has a very high mortality rate.

CT features include perilobular reticulations with a ground glass pattern, an nonsystematic alveolar condensations. When the edema is cardiogenic, it is associated with the presence of pleural effusions including on the non-operated side.



Figure 1. Axial CT with a mediastinal window following intravenous iodinated contrast administration in a 60-year-old patient. The image shows a pleural effusion with heterogenous enhancement due to a hemothorax that developed during ablation of the chest tube with extravasation along the pathway of the drain due to an intercostal injury (arrow). Surgical management during CT with clot washing.

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