Atelectasis will generally show signs of diminished lung volume, while pneumonia causes increased volume.

Fig. 2.76 **Pneumonia versus atelectasis—enhancement characteristics.**
Atelectasis shows intense homogeneous enhancement (posterior) contrasting with the slight, inhomogeneous enhancement of the infiltrate (anterior).

pneumonic consolidation on chest radiographs when there are no signs of diminished volume (atelectasis) or increased volume (pneumonia). Both conditions—atelectasis and infectious infiltration—may be responsible for lobar consolidation.

The following points are helpful:

- If an opacity interpreted as atelectasis becomes larger and more ill defined over time, it is more likely to be a pneumonic infiltrate. Any atelectasis that does not resolve within a matter of days is also suspicious for infectious infiltration (**Fig. 2.75**).
- CT can differentiate atelectasis and pneumonic consolidation by their different enhancement characteristics after contrast administration: Atelectatic lung shows intense homogeneous enhancement while pneumonic lung tissue shows much weaker, inhomogeneous enhancement (**Fig. 2.76**).
- A positive air bronchogram may be found in both atelectasis and pneumonia, so it is *not* a useful differentiating sign. The absence of an air bronchogram in atelectasis signifies a central bronchial obstruction due to mucoid impaction (see **Fig. 2.73b**).

Pneumothorax

E. Eisenhuber-Stadler and S. Metz-Schimmerl

Pneumothorax is a relatively common and important finding in the ICU, especially in ventilated patients. Pneumothorax may have an iatrogenic cause in ICU patients and may result from surgery, barotrauma, or catheter-related complications (**Table 2.38**). Rare causes of pneumothorax are blunt or penetrating thoracic trauma and mediastinal emphysema with the secondary development of a pneumothorax.

A pneumothorax may develop hours or even days after successful (or unsuccessful) pleural drainage. It may also result from suboptimal placement of a thoracostomy tube.

A pneumothorax may still develop hours or days after a tube thoracostomy.

Table 2.38 Causes of pneumothorax in ICU patients

Iatrogenic (common):
▪ Barotrauma
▪ Central venous catheter
▪ Thoracentesis, thoracostomy
▪ Cardiac massage
Blunt or penetrating thoracic trauma (rare):
▪ Mediastinal emphysema with secondary pneumothorax
▪ Tracheobronchial injuries
▪ Tracheotomy
▪ Barotrauma
▪ Tracheal or esophageal perforation

Treatment. An acute pneumothorax (without septations) can be drained through an 8–10F catheter which is usually placed in the second intercostal space in the midclavicular line (anterior) or in the sixth to eighth intercostal space in the midaxillary line. With a loculated pneumothorax, the drains should be placed under CT or ultrasound guidance.

Diagnostic Strategy

The method of first choice is the *portable chest radiograph*. If the frontal view does not yield a clear diagnosis, other options are to obtain a lateral chest radiograph (difficult to position), a lateral decubitus view, or a tangential view.

The most rewarding imaging modality in patients with clinical suspicion of an occult pneumothorax is *computed tomography*.

Increasingly, *ultrasonography* is being used as a bedside study for the diagnosis of pneumothorax.

Imaging

Radiography and Computed Tomography

Localization. In the supine patient, the classic signs of pneumothorax are seen only with a relatively large intrapleural air collection and a compliant lung (**Fig. 2.77**). Air in the supine patient tends to be distributed in the anterior and basal portions of the pleural space (**Table 2.39**). Sites of predilection in supine patients are anteromedial and subpulmonic (**Fig. 2.78**). Anterior air collections on the AP chest radiograph may easily escape direct detection. Watch for these signs:

- a sharp diaphragm silhouette
- a rounded or oval-shaped area of increased lucency ("black oval")
- an avascular area

Volume estimation. The extent of a pneumothorax is difficult to estimate on portable chest radiographs. Suction

Fig. 2.77 **Pneumothorax.**
The classic radiographic signs of pneumothorax are seen only with a large air collection and a compliant lung.

In a supine patient with pneumothorax, the air tends to be distributed in the anterior and basal portions of the pleural space.

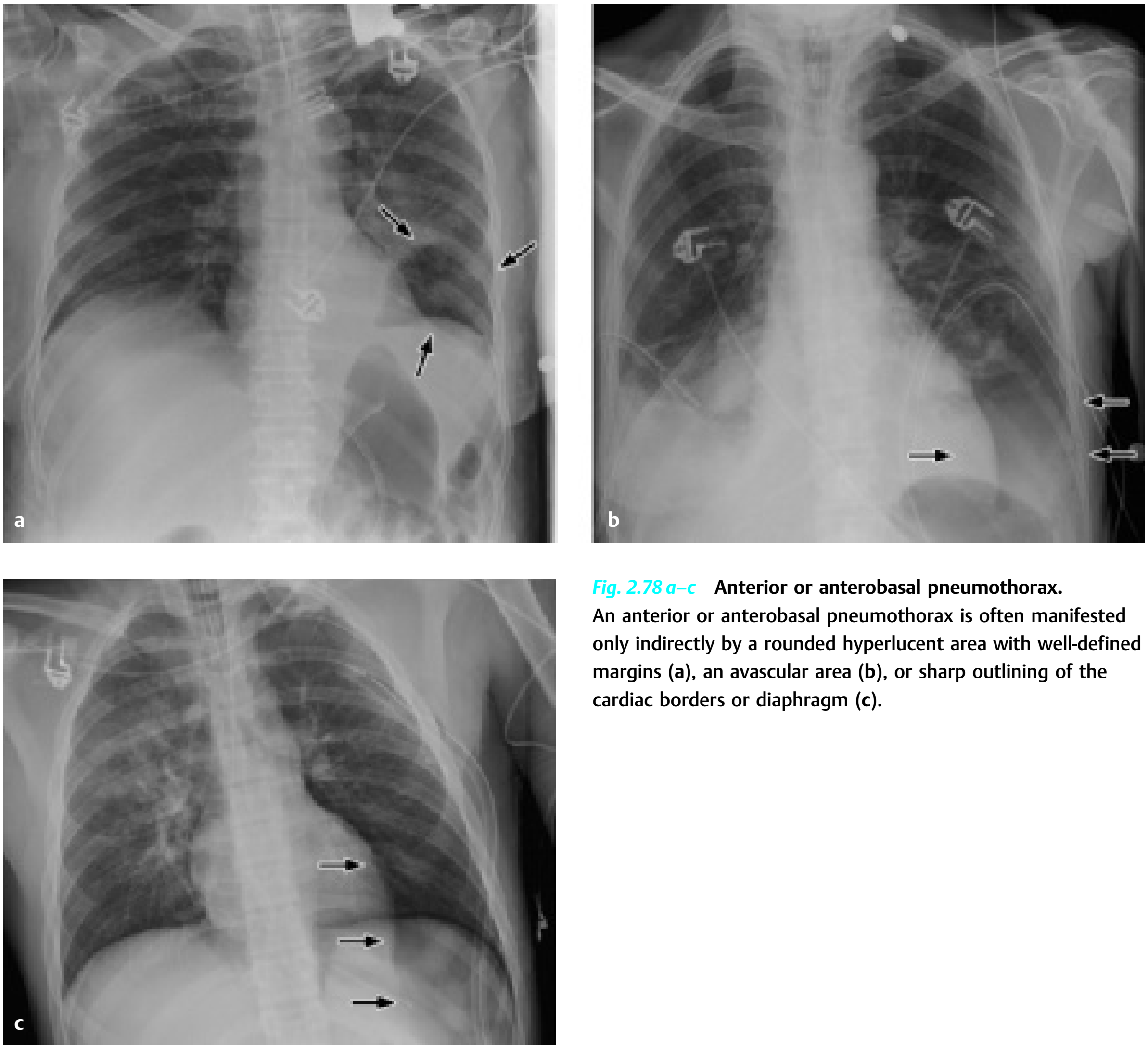

Fig. 2.78 a–c **Anterior or anterobasal pneumothorax.**
An anterior or anterobasal pneumothorax is often manifested only indirectly by a rounded hyperlucent area with well-defined margins (**a**), an avascular area (**b**), or sharp outlining of the cardiac borders or diaphragm (**c**).

Table 2.39 **Location and radiographic signs of pneumothorax in the supine patient**

Location	Indirect signs of pneumothorax
Anteromedial pneumothorax	**Suprahilar** ▪ Sharp outlining of: – superior vena cava – azygos vein – left subclavian artery – superior pulmonary vein ▪ Contralateral displacement of anterior pleural reflection
	Infrahilar ▪ Sharp outlining of: – cardiac border – inferior vena cava – cardiophrenic angle – medial part of diaphragm below cardiac silhouette – pericardial fat pad
Subpulmonic pneumothorax (chest radiograph must include the upper abdomen)	▪ Hyperlucent upper quadrant ▪ Deep costophrenic sulcus (deep sulcus sign) ▪ Sharp outlining of the diaphragm ▪ Appearance of a second diaphragm shadow (“double diaphragm sign”) ▪ Delineation of inferior vena cava
“Classic” apicolateral pneumothorax	▪ Lack of contact between the minor fissure and chest wall

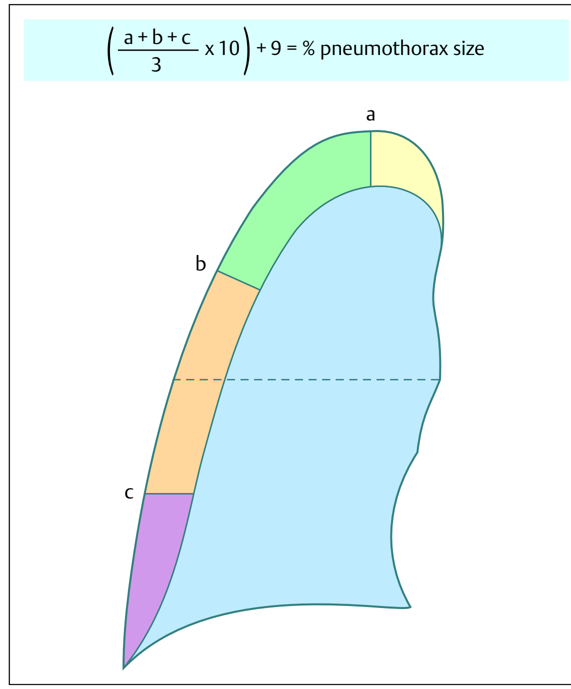

Fig. 2.79 **Estimation of pneumothorax size using the formula of Choi et al. (1998).**

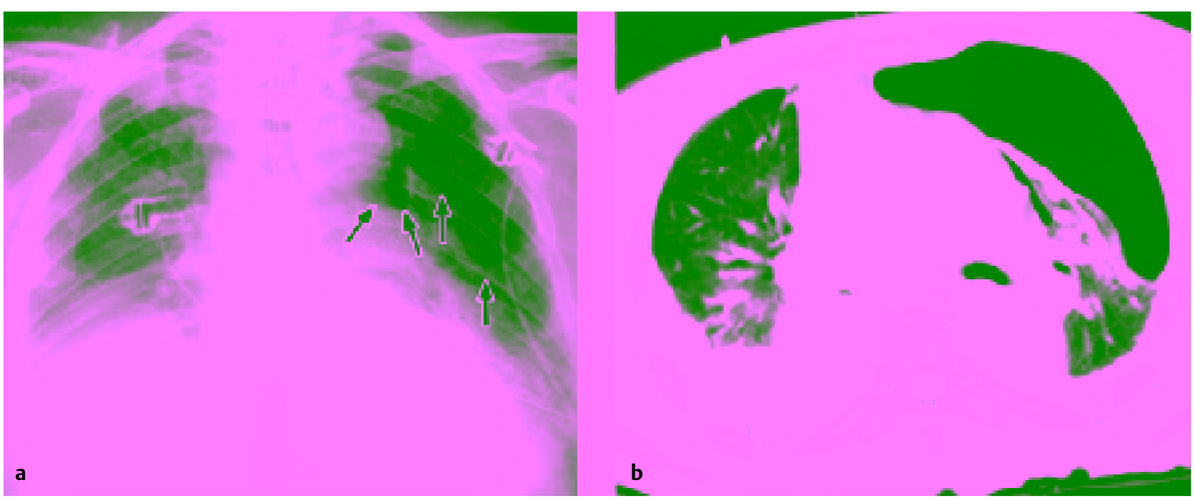

Fig. 2.80 a, b **Gross underestimation of pneumothorax size in the supine radiograph.** Chest radiograph (**a**) and CT scan (**b**) of the same patient taken 2 hours apart.

drainage is indicated if more than 35 % of the lung volume is affected. The indication for drainage depends on clinical manifestations, a visual volume assessment on the chest radiograph, and on tension signs.

Choi et al. (1998) described a formula for estimating the volume of a pneumothorax. The average interpleural distances are measured at apical, lateral, and laterobasal locations and are used in the following formula:

$([a+b+c]/3 \times 10)+9 =$ percentage pneumothorax size (**Fig. 2.79**)

One limitation of this formula is that the pneumothorax must extend along the lateral chest wall and must be defined there. We know from experience, however, that the anterior pneumothorax in supine patients may reach a considerable size without displaying clear outlines, resulting in a gross underestimation of pneumothorax size on the chest film (**Fig. 2.80**). If radiographic findings are equivocal, CT should be used for the detection, localization, and quantification of pneumothorax, even in preparation for chest tube placement.

Barotrauma. The detection or exclusion of pneumothorax may be difficult or impossible when subcutaneous empyema (e. g., due to barotrauma) is superimposed on the

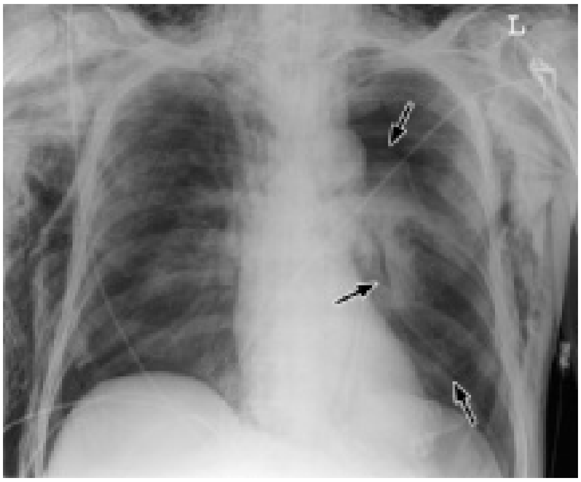

Fig. 2.81 **Pneumothorax with superimposed soft-tissue emphysema.**
A pneumothorax is particularly difficult to detect when accompanied by soft-tissue emphysema.

radiograph (**Fig. 2.81**), and CT may be appropriate in these cases. Premonitory signs of barotrauma are interstitial emphysema after the rupture of interstitial septa, which may be followed by air dissection to the mediastinum (mediastinal emphysema) and into the soft tissues (soft-tissue emphysema; see p. 46).

The risk of pneumothorax in barotrauma is significantly increased when the hemidiaphragm is lower than the sixth anterior rib segment or when the craniocaudal extent of the lung is greater than 25 cm.

Ultrasonography

In the absence of pneumothorax, the ultrasound scan shows *lung sliding* along the echogenic pleural interface during inspiration and expiration. It also shows *comet tail artifacts*, which are high-level reverberations extending from the pleural line to the lower edge of the screen (**Fig. 2.82**). With pneumothorax, both criteria are absent because of air in the pleural space. The absence of lung sliding during respiration is considered to have a negative predictive value of 90–100 % and a false-positive rate of 10 %.

Ultrasonography can be a useful diagnostic aid in bed-confined patients with equivocal radiographic findings.

Differential Diagnosis

Skin folds. Mistaking skin folds for pneumothorax on chest radiographs is most likely to occur in elderly and cachectic patients. Skin folds typically extend beyond the chest wall, are often multiple or bilateral, disappear suddenly, and are traversed by vascular structures (**Fig. 2.83**). Other signs of skin folds are indistinct margins, an associated soft-tissue shadow, and nonparallel alignment relative to the chest wall. Skin folds are easy to recognize as a rule, and only rarely do they require repeating the chest radiograph under controlled conditions or proceeding with CT.

Other air collections. The following intra- and extrathoracic air collections may not be misinterpreted as pneumothorax: lung cysts, emphysematous bullae, pneumatoceles, air collections in the mediastinum, pericardium or thoracic soft tissues, intrathoracic hernias (**Fig. 2.84**).

There is significant risk of pneumothorax due to barotrauma when the craniocaudal extent of the lung exceeds 25 cm and the diaphragm leaflets are lower than the sixth anterior rib segment.

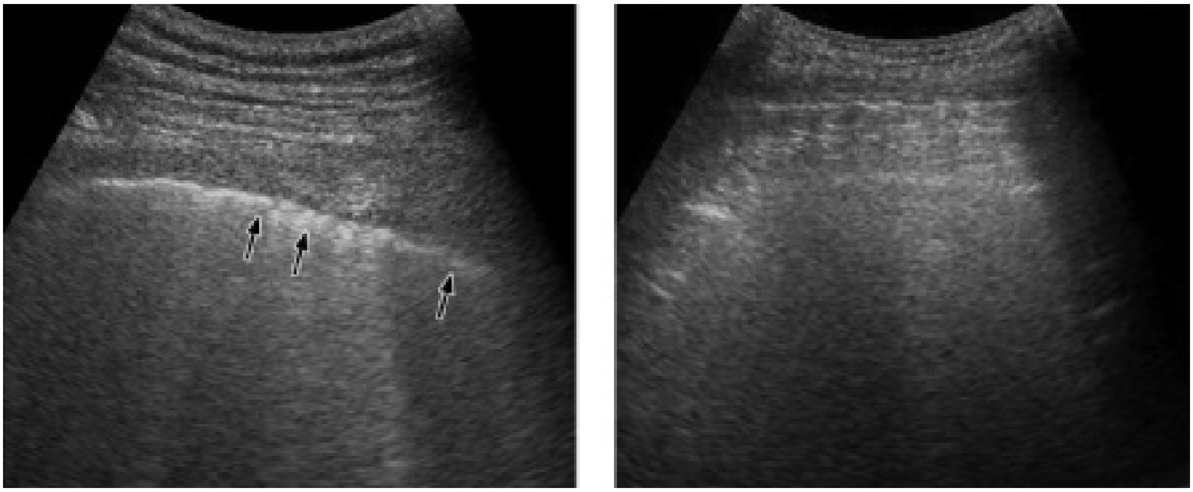

Fig. 2.82 a, b **Ultrasonographic appearance of pneumothorax.** A characteristic feature of pneumothorax by ultrasound scan is the lack of the comet tail caused by absence of the pleural line (**a**) compared with normal findings (**b**) (with kind permission of F. Gleeson, Oxford, UK).