The assessment of ventilation distribution is an important clinical parameter for many respiratory disorders. It yields additional information compared to pulmonary function tests, as morphological changes and regional distribution of disease can be visualized. Furthermore, dynamic assessment using paired inspiratory and expiratory imaging is capable of predicting lung function. Thus, ventilation computed tomography (CT) aims to determine the distribution of inspired air in a quantitative, time-resolved and regional fashion. The amount of air in the distal airways will result in changes in density, allowing quantification of air distribution on a regional basis and the assessment of small airway diseases as inspired air becomes trapped at expiration. It is this additional information that makes imaging of ventilation distribution so valuable.

Computed tomography (CT) is the current work-horse of clinical radiology and is described more extensively in Chap. 3–6. Ventilation CT has benefited from the introduction of the slip-ring technology, which made it feasible to speed up the data acquisition process and allowed volumetric data recording (helical or spiral CT). The availability of faster and more powerful computers has allowed the development of image reconstruction algorithms that helped speed up image acquisition or alternatively improve image clarity. The development of multiple detector rows (multi-detector or multi-slice CT) has made it possible to acquire larger volumetric data sets and further increase the speed of imaging or alternatively decrease slice thickness. Thus, present day CT allows a range of diagnostic techniques to be employed, and several strategies may be used for imaging of the lungs.

Imaging of the lung may consist of anatomical (parenchymal) imaging and functional imaging. At present, routine clinical imaging of the lung parenchyma is performed using chest radiography and computed tomography (CT). CT is the gold standard imaging modality for the morphological assessment of the pulmonary parenchyma with high spatial resolution (slice thickness 1 mm or less). Dedicated strategies are applied to estimate lung function (Kramer and Hoffman 1995). By using paired inspiratory and expiratory scans, hypoventilated lung areas caused by expiratory obstruction, i.e. air trapping can be detected (Kauczor et al. 2000). In addition, dynamic CT (spiral CT without table movement) is feasible. A temporal resolution of 100 ms can be reached (Markstaller et al. 2001a). However, this approach is limited to one slice. Larger coverage can be achieved by the use of multi-detector (“multi-slice”) CT. The whole lung can be scanned within 5 seconds. This temporal resolution is not suited to derive functional parameters. Attempts of direct visualization of ventilation using CT consist of Xenon-enhanced CT and the use of an aerosolized contrast agent. Both techniques aim at an increase of lung density reflecting regional ventilation. The increase in density is rather small and further post-processing is required (Thiele and Klöppel 1995; Simon et al. 1998). Thus, the use of CT for functional assessment of ventilation is improving using a variety of newly developed techniques.
High Resolution Computed Tomography

High resolution CT (HRCT) is controlled by three main factors (Webb et al. 2001). First, a narrow beam collimation of 1–1.5 mm is used in order to reduce volume averaging and increase spatial resolution (Naidich et al. 1985; Nakata et al. 1985; Zerhouni et al. 1985; Mayo et al. 1987). Secondly, the high spatial frequency reconstruction algorithm used takes advantage of the inherent high contrast between air and soft tissues, thus allowing increased sharpness of the structures at high spatial resolution (Mayo et al. 1987; Murata et al. 1988). Finally, the application of a small field-of-view (FOV) increases the spatial resolution further. This can be achieved by image targeting after the initial data set has been acquired. The reduction of the FOV results in a decrease in pixel size with corresponding increase in spatial resolution (Mayo et al. 1987; Murata et al. 1989).

The introduction of volumetric CT scan protocols has the advantage of greater lung coverage, more complete assessment of the lung and the potential to reconstruct images in different (non-axial) planes. Several studies have used maximum intensity projection images to demonstrate that the identification of pulmonary nodules may be improved in general (Bhalla et al. 1996; Remy-Jardin et al. 1996), although there is a potential problem in very extensive disease with superimposition of opacities (Remy-Jardin et al. 1996). The usefulness of multidetector CT on workflow related issues was demonstrated in a recent study in 50 patients with suspected or confirmed interstitial lung disease (Remy-Jardin et al. 2002a). This study showed that the number of images to be interpreted could be reduced by 40%, without affecting diagnostic accuracy, if a coronal plane was reconstructed rather than the routine axial plane.

HRCT is usually performed during suspended full inspiration. This improves the inherent air-soft tissue contrast as the alveoli and airways are fully distended, revealing the interstitial tissues more clearly (Fig. 7.2.1a). Furthermore, full inspiration by its very nature reduces (gravity dependent) transient collapse of lung segments, which will take place in a physiological setting due to the weight of the lung tissue if insufficient insufflation has taken place (Fig. 7.2.1b). In addition to the inspiratory images, suspended forced post-expiratory HRCT scans are useful in patients with obstructive lung diseases (Webb 1987). Post-expiratory HRCT will enhance the obstruction, leading to air being trapped due to early collapse or obstruction of small airways, thus enhancing the diagnostic potential of HRCT (Arakawa and Webb 1998). Air trapping may be focal or diffuse, and is shown by a relative decrease in density compared to normal lung tissues. Air trapping corresponds reasonably well with pulmonary function tests (Arakawa and Webb 1998; Chen et al. 1998; Lucidarme et al. 1998) and can help to distinguish between increased lung opacity as seen in infiltrative lung disease and air trapping as seen in obstructive lung disease (Arakawa et al. 1998).

Motion artifacts becomes an issue in the lung zones adjacent the heart. One way of minimizing motion effects is to obtain images in sub-second scan

---

Fig. 7.2.1. a High-Resolution CT at full inspiration with patient supine. b High-Resolution CT at expiration shows gravity dependent increased attenuation of dependent lung tissue (patient supine). Note the change in calibre of the main bronchi during expiration