5 CT and MRI of Pulmonary Emphysema: Assessment of Lung Structure and Function

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5.1 Computed Tomography

5.1.1 Introduction

Computed tomography (CT) is a radiological modality that provides transverse anatomical images. In these images, the value of each picture element (pixel) corresponds to the X-ray attenuation of a defined volume of tissue (voxel). The X-ray attenuation values for each set of projections (slice) are registered by a computer and organized in the form of a matrix. The number of calculated pixels not only determines the image matrix size, but also impacts on the image resolution, and should therefore be as high as possible. In clinical practice, the matrix size is 512×512 pixels. The X-ray attenuation, that is sometimes termed “tissue density”, is numerically expressed in Hounsfield units (HU). The scale of attenuation values ranges from –1000 HU, corresponding to the attenuation value of air, to 3000 HU, with 0 HU corresponding to the attenuation value of water. The thousands of pixels and respective attenuation values included in one scan make CT the most precise modality for the in vivo assessment of pulmonary parenchyma (Hoffman and McLennan 1997).

In addition to providing overall anatomical information as to lung tissue destruction, the major advantage of CT in patients with emphysema is that it also identifies the specific pulmonary locations where the alveolar surface has been destroyed (Fig. 5.1). The ability to estimate the extent and severity of pulmonary emphysema in vivo appears important for several reasons:

1. Early accurate detection of lung destruction and mapping of its progression are required to understand the natural history of emphysema.
2. The treatment of advanced emphysema by lung volume reduction surgery (LVRS) requires knowledge of the location of emphysematous lesions and objective methods for evaluating post-surgical results (Gierada et al. 1997).
3. CT could be a sensitive modality for quantifying the progression of emphysema when determining the efficacy of replacement therapy in patients with a1-antitrypsin deficiency (Dirksen et al. 1999).
4. Studies suggesting that alveolar number and surface-to-volume ratio can be restored by drugs in rats with elastase-induced emphysema imply the future need for measurements that can accurately assess the therapeutic effect of such therapies (Stockley 2000; Tepper et al. 2000).
5. The detection of early emphysema may prevent the occurrence of obstructive ventilatory impairment by smoking cessation or other medical interventions (Morgan 1992).

Numerous studies have addressed the capability of CT to accurately quantify the extent and the severity of pulmonary emphysema (Stern and Franck 1994; Thurlbeck and Müller 1994). To verify whether CT is adequately validated and to suggest possible directions for future research, this article provides an overview over previously published studies, often based on widely varying models. Studies have indeed been based on subjective visual grading or on objective indexes derived from attenuation values, on two-dimensional or on three-dimensional approaches, and on CT scans obtained at either full suspended inspiration or full suspended expiration.

Pulmonary emphysema is defined as “abnormal permanent enlargement of the air spaces distal to the terminal bronchioles, accompanied by destruction of the alveolar walls, and without obvious fibrosis”. Because this definition is based on pathology, new modalities for diagnosis and quantification of emphysema must be validated by comparisons with this standard of reference (Snider et al. 1985). However, the presence and extent of emphysema can be determined by both macroscopic and microscopic assessment of lung specimens. Before discussing the CT-related issues in the quantification of emphysema, we will thus first briefly review the most widely used macroscopic and microscopic methods used in emphysema quantification.

5.1.2 Histopathological Quantification of Pulmonary Emphysema

5.1.2.1 Macroscopic Methods

Two methods were traditionally used to macroscopically quantify the severity of emphysema: point counting developed by Dunnill (1962b), and panel grading proposed by Thurlbeck et al. (1970). Point counting calculates the proportion occupied by emphysematous spaces expressed as a percentage of a lung section by using a transparent plastic sheet with a grid drawn on it and placed on the lung section. The points of this grid lie 1 cm apart and are situated at the angles of equilateral triangles with 1 cm sides. The percentage of the lung involved by emphysema is given by the number of points superimposed on emphysematous spaces multiplied by 100 and divided by the number of points on the whole lung section. This method is truly quantitative and can be performed on several sections obtained throughout a lung specimen, but it is tedious and time-consuming. Panel grading is based on the comparison of paper-mounted sagittal lung sections with a set of standards that score emphysema from 0 to 100 at intervals of 5 or 10. Scores of 5–25 indicate mild emphysema, scores ranging from 30–50 indicate moderate emphysema and scores of 60 or more correspond to severe emphysema (Thurlbeck et al. 1970). Panel grading is relatively quick. However, rather than being truly quantitative, it is a method