High-resolution computed tomography (HRCT) dominates the recent literature about the imaging of diffuse lung diseases. The detailed images of the lungs available from HRCT occupy the middle ground between the sometimes vague impressions provided by chest radiography and the microscopic, but necessarily localised, information obtained from a lung biopsy. The evidence accumulated so far allows a reasonably objective view to be taken of the value and limitations of HRCT. The main uses of HRCT (Table 1) have changed little since its introduction 15 years ago, and reflect the increased confidence that this procedure is able to bring to the diagnosis of diffuse lung disease. More recently, the role of HRCT has been broadened to include the evaluation of disease reversibility and the identification of various forms of small airways disease.

### Technical considerations

The key factors that define the HRCT technique are thin sections, widely spaced, with the data reconstructed without any ‘smoothing’ of the image. Despite this apparently simple definition, there may be striking differences in the appearances of images of the same patient obtained on two different CT scanners, even when the same technical factors are applied. Such discrepancies rarely cause diagnostic confusion (and are analogous to the sensation of playing tennis with an unfamiliar racquet). The two basic advantages of the HRCT technique are:

- the ability to identify fine parenchymal detail (Fig 1)
- a reduction in radiation dose at least sixfold compared with conventional CT protocols.

The effective radiation dose from a standard HRCT protocol is about 12 times that of a frontal and lateral chest radiograph.

HRCT should not be confused with spiral (also known as helical or continuous volume) CT scanning. Spiral CT involves the continuous acquisition of data by moving the patient table continuously into the CT scanner such that a ‘corkscrew’ or spiral of information is acquired. The data can be reconstructed in many ways, but are most usually presented as a series of conventional-looking (thick) transaxial sections. However, spiral CT is not necessary for the routine evaluation of diffuse lung disease.

### Table 1. Roles of high-resolution computed tomography.

<table>
<thead>
<tr>
<th>Role</th>
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<tr>
<td>- to detect diffuse lung disease in patients with a normal or near normal chest radiograph and/or abnormal lung function tests</td>
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<tr>
<td>- to narrow the differential diagnosis or make a confident histospecific diagnosis in patients with obvious but non-specific radiographic abnormalities</td>
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<tr>
<td>- to investigate patients with suspected bronchiectasis or unexplained severe obstructive airways disease</td>
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<tr>
<td>- to guide the type and appropriate site of lung biopsy</td>
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<tr>
<td>- to assess disease reversibility, particularly in patients with fibrosing lung disease</td>
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**Erratum**

Vol 33 No 4, July/August 1999
CME NEUROLOGY – II

German Berrios

New drug treatments in psychiatric disease

We regret the statement on page 310 that ‘Olanzepine seems to cause less agranulocytosis and lowering of seizure threshold than risperidone or clozapine because it does not antagonise alpha₂ adrenoreceptor function.’

**This should have read:** ‘Olanzepine is similar to clozapine in molecular structure and in having greater 5HT₂ than D₂ blockade, but does not antagonise alpha₂ adrenoreceptor function, as do risperidone and clozapine; it has not been associated with agranulocytosis or lowering of seizure threshold.’

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*J R Coll Physicians Lond* 1999;33:525–31

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Basic high-resolution computed tomography anatomy and signs

There is close correspondence between the abnormalities seen on HRCT images and the macroscopic appearance of pathological specimens. Because of this correlation, precise anatomic terms can be used to describe many of the HRCT patterns of diffuse lung disease, rather than the sometimes whimsical terms used to describe its radiographic appearances. The smallest structures visible on HRCT images are less than 1 mm and may be less than 200 μm. Thus, the occasional interlobular septa, which are approximately 100 μm thick, will be visible in the lung periphery in healthy individuals (Fig 2). The interlobular septa bound the secondary pulmonary lobules (which is regarded as the smallest anatomical unit of the lung surrounded by a connective tissue septum). Since many diffuse lung diseases have a characteristic distribution in relation to the secondary pulmonary lobules, it is useful to consider abnormalities seen on HRCT in terms of their relationship to the various components of the secondary pulmonary lobule.

The most frequently encountered HRCT signs of disease, namely a reticular or nodular pattern and ground glass opacification (GGO), can be briefly reviewed by considering the HRCT appearances of four of the commonest diffuse lung diseases: cryptogenic fibrosing alveolitis, lymphangitis carcinomatosa, sarcoidosis and extrinsic allergic alveolitis (subacute) (Fig 3(a)–(d)).

Ground glass opacification

The greatest number of problems in interpreting HRCT images is caused by GGO; at its most subtle, it is an almost imperceptible and uniform increase in density of the lung parenchyma, such that the lungs appear slightly grey by contrast to the darker air within the bronchi (the ‘black bronchus’ sign). Such minor density differences are susceptible to many technical vagaries. Furthermore, an increase in lung density, indistinguishable from widespread GGO, occurs in normal individuals breath-holding at near residual volume. When GGO is patchy in distribution, it is readily recognisable.

At a histological level, the changes responsible for GGO may be complex, and include partial filling of the air spaces, considerable thickening of the interstitium or a combination of the two. It needs to be appreciated that this pattern is in itself diagnostically nonspecific, but other HRCT features often help to refine the differential diagnosis (see Fig 3(d)). Diseases characterised by patchy or uniform GGO are listed in Table 2.

Importantly, GGO usually represents
A potentially reversible lung disease, but there are exceptions. Widespread fine intralobular fibrosis may also produce a pattern of GGO, but in this situation there is usually accompanying distortion and dilatation of the bronchi ('traction bronchiectasis') (Fig 4). It is erroneous simply to equate GGO on HRCT images with 'active alveolitis'.

Patchy density differences in the lung parenchyma (often referred to as a mosaic attenuation pattern) may be seen in patients with conditions that result in regions of underperfused lung.

This situation occurs in patients with a primarily vascular disease, for example chronic thromboembolic disease. In patients with airways disease, areas of underventilated (and consequently underperfused) lung are of decreased attenuation relative to areas of overperfused lung which appear as areas of GGO. In these situations, the vessels within the apparent areas of GGO will appear engorged (Fig 5).

One of the greatest challenges in HRCT interpretation is the recognition of GGO (most often in the face of a normal chest radiograph), and the assimilation of this basic sign with other HRCT features to determine whether the cause is infiltrative lung disease, vascular disease or small airways disease.

Diagnostic accuracy of high-resolution computed tomography

The improved sensitivity of HRCT over chest radiography and, in some instances, lung function testing, has been shown in a number of conditions.
For example, in one study of patients with extrinsic allergic alveolitis 11/14 (79%) of HRCTs showed GGO compared with only 5/14 (36%) on chest radiography. In many of the connective tissue diseases, notably rheumatoid arthritis, systemic sclerosis and Sjögren’s syndrome, HRCT reveals a variety of coexisting interstitial and airway abnormalities, often at a stage when patients are asymptomatic and have an apparently normal chest radiograph.

It is impossible to combine the evidence from many of the studies that have compared the sensitivity of HRCT to chest radiography because of differences in CT scanning technique, observer experience and patient selection. However, those studies that can be compared show that the average sensitivity of HRCT for the detection of diffuse interstitial lung disease is approximately 94%, compared with 80% for chest radiography. The superior sensitivity of HRCT reflects its ability both to detect extremely subtle density differences in the lung parenchyma, for
example in cases showing emphysema or GGO, and also to show disease in radiographically inaccessible parts of the lung, for example early fibrosing alveolitis in the costophrenic recesses (Fig 6). Several rudimentary image processing techniques can be used to enhance the ability of HRCT to detect extremely subtle parenchymal abnormalities\(^\text{11,12}\), but these are time-consuming and are not routinely applied.

The increased sensitivity of HRCT compared to chest radiography is not, as is often the case with diagnostic tests, achieved at the expense of reduced specificity: false-positive diagnoses of diffuse lung disease are relatively uncommon with HRCT, in contrast to the frequent difficulty of deciding whether or not a chest radiograph shows real diffuse lung disease.

Several diffuse lung conditions have a more or less diagnostic appearance on HRCT. Thus, the appearance of bizarre-shaped cavitating lesions concentrated in the upper lobes is virtually pathognomonic of Langerhans cell histiocytosis (Fig 7). By contrast, the relatively recently defined histopathological entity of non-specific interstitial pneumonitis has a wide variety of parenchymal patterns and distributions on HRCT – to the extent that there is some question as to whether a condition with such a heterogeneous appearance should be considered a single disease entity (Fig 8).

With increasing experience, several conditions are now regarded as having a diagnostic appearance on HRCT (Table 3), such that lung biopsy of any sort is rarely sought provided that the HRCT features and clinical picture are compatible. Nevertheless, it is easy to overlook the fact that several diffuse lung diseases have reasonably characteristic appearances on a plain chest radiograph. In this respect, the diagnostic gain of HRCT over chest radiography is sometimes overstated in, for example,
fibrosing alveolitis with its typical basal reticulonodular pattern. However, it is the added confidence that HRCT brings to the diagnosis of many diffuse lung diseases that is one of its most important assets. The greater degree of confidence, which is not easily quantified in clinical studies, was first highlighted by Mathieson et al., and has been subsequently reiterated.

The confidence with which an HRCT diagnosis of specific diffuse lung disease can be made depends heavily on experience. This is borne out in the sequence of published descriptions of the HRCT appearances of extrinsic allergic alveolitis. Early reports suggested that the findings of GGO and a faint nodular pattern were non-specific, whereas more recent studies support that this constellation of signs is virtually diagnostic.

Other uses of high-resolution computed tomography

The clinical use of HRCT is not confined to diagnosis. HRCT can be used both to delineate precisely the extent of disease and to gauge disease reversibility (more controversially termed ‘disease activity’). The HRCT signs which denote reversible disease are largely applicable, irrespective of the histopathological diagnosis (listed in Table 4). These secondary uses of HRCT have been mainly applied to patients with fibrosing alveolitis in which the extent and pattern shown on HRCT are strongly predictive of response to treatment and prognosis. HRCT has elucidated the sometimes complex mixed obstructive and restrictive functional abnormalities found in some diffuse lung diseases such as extrinsic allergic alveolitis, sarcoidosis and fibrosing alveolitis admixed with emphysema. Specifically, patients with fibrosing alveolitis and coexisting centrilobular emphysema may have apparently normal lung volumes as measured by plethysmography (because of the opposing functional effects of the two diseases), and a strikingly low gas diffusing capacity. The coexistence of these two diseases, responsible for spuriously normal lung volumes, can be

Table 3. Diffuse (interstitial and airways) lung diseases with ‘diagnostic’ high-resolution computed tomography appearances.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
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<tr>
<td>cryptogenic fibrosing alveolitis (usual interstitial pneumonitis histological subtype)</td>
<td></td>
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<tr>
<td>centrilobular emphysema</td>
<td></td>
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<tr>
<td>sarcoidosis</td>
<td></td>
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<tr>
<td>Langerhans cell histiocytosis</td>
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<tr>
<td>extrinsic allergic alveolitis (subacute)</td>
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<tr>
<td>lymphangioleiomyomatosis</td>
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<tr>
<td>alveolar proteinosis</td>
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<tr>
<td>bronchiectasis</td>
<td></td>
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<tr>
<td>constrictive obliterative bronchiolitis</td>
<td></td>
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<tr>
<td>diffuse panbronchiolitis</td>
<td></td>
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</tbody>
</table>

Fig 8. Biopsy proven non-specific interstitial pneumonitis. There is a combination of nodular and reticular patterns with ground glass opacification elements in a non-specific distribution.

Key Points

- High-resolution computed tomography (HRCT) lends precision to the detection of early diffuse infiltrative lung disease, particularly when interpreted in conjunction with lung function tests
- The degree of diagnostic advantage of HRCT over chest radiography is disease-specific and does not apply equally to all diffuse lung diseases
- Several diffuse lung diseases have sufficiently characteristic appearances on HRCT to obviate the need for biopsy confirmation of the diagnosis
- Estimation of disease reversibility and prognostic information can be extracted by careful interpretation of HRCT images, especially in fibrosing lung disease
readily recognised on HRCT images. Careful study of the morphological characteristics on HRCT of other diffuse lung diseases will doubtless yield further pathophysiological insights.

Table 4. Summary of reversible patterns on high-resolution computed tomography.

<table>
<thead>
<tr>
<th>Pattern of disease</th>
<th>Reversibility</th>
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<tbody>
<tr>
<td>Ground glass opacification</td>
<td>+++/-</td>
</tr>
<tr>
<td>Air space consolidation</td>
<td>++/-</td>
</tr>
<tr>
<td>Nodular pattern</td>
<td>+/-</td>
</tr>
<tr>
<td>Interlobular septal thickening</td>
<td>+/-</td>
</tr>
<tr>
<td>Reticular pattern with architectural distortion</td>
<td>——</td>
</tr>
</tbody>
</table>

+ = reliability of sign of reversible disease; — = reliability of sign of irreversible disease.

References


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