Use of imaging in the management of malignant pleural mesothelioma

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Received 26 January 2005; received in revised form 23 May 2005; accepted 25 May 2005

KEYWORDS
Mesothelioma; Pleura; Computed tomography; CT; Biopsy

Malignant pleural mesothelioma (MPM) is an increasingly prevalent tumour. The death rate associated with MPM is predicted to peak in the next 10 years, although radiologists and clinicians will be encountering cases for the next few decades. Contrast-enhanced CT is an established technique for evaluating suspected malignant pleural disease, but MPM can be reliably diagnosed only by histological sampling. However, even with adequate sampling and the use of immunocytochemistry, histological diagnosis is known to be difficult; definitive diagnosis may involve a combination of clinical presentation, radiological and histological appearances. Percutaneous biopsy is a promising technique for sampling the pleura. In view of its pattern of growth, MPM is a challenging disease to image by any method, and it behaves quite differently from lung cancer. This review aims to highlight the practical aspects of assessing malignant pleural mesothelioma.

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Introduction

Malignant pleural mesothelioma (MPM) currently accounts for 1700 deaths per year in the UK, but is forecast to peak at 1950 to 2450 deaths per year between 2011 and 2015. Although the peak of the epidemic may last for 10 to 15 years, the tail may last until 2050.1,2 MPM is predicted to become one of the more common cancers, with a higher mortality than melanoma, uterine or cervical cancer.1 Men born in the late 1940s are predicted to be at the highest risk of dying from MPM3 and, although rare in the first 10 to 15 years after exposure to asbestos, the risk of mesothelioma increases thereafter with time.4,5 MPM has a high association with asbestos exposure,5 but there is no relevant history in up to 20% of cases.6 MPM should be considered in all cases of unilateral pleural abnormalities and chest pain, and in cases of chest pain with a history of asbestos exposure.

The biological behaviour of MPM is very different to that seen in lung cancer, and there are many difficulties in diagnosis, staging and assessment of response. There are a number of ongoing or planned trials in the UK. Surgery may have a role in a limited number of cases, and preoperative assessment holds further challenges. We present a review of the radiological techniques involved in the management of MPM.

Pleural anatomy and lymph node drainage

The anatomy of the pleura is complex and is not always appreciated.7 The inferior margins of the pleura in the posterior costodiaphragmatic recesses of the hemithorax extend considerably lower than the corresponding border of the lung, to the level of the 12th dorsal vertebra. The diaphragm extends more inferiorly, and the right crus arises from
the anterolateral surfaces of the bodies and intervertebral discs of the upper three lumbar vertebrae. In cases of established mesothelioma being considered for radical treatment, the entire pleural and diaphragmatic surfaces need to be scanned contiguously from the thoracic inlet to the level of the third lumbar vertebra. This allows coronal and sagittal images to be reconstructed.

The lymphatic drainage of the pleura is equally complex. Although the visceral pleural lymphatics follow the same pattern of drainage as the lung, the lymphatic drainage of the parietal pleura is very different. The anterior parietal pleura drains to internal mammary nodes. The posterior parietal pleura drains to extrapleural lymph nodes, which lie in the paraspinal fat adjacent to the heads of the ribs. The diaphragm is commonly involved in MPM; the anterior and lateral diaphragmatic lymphatics drain to internal mammary and anterior peridiaphragmatic nodes. The posterior diaphragm drains to para-aortic and posterior mediastinal nodes. There are free anastomoses between lymphatics on both surfaces of the diaphragm, and coeliac axis or gastrohepatic nodal enlargement may be seen. In practice, the lymphatic drainage can be thought of as a circle of nodes in the extrapleural space. Any nodes visualized here should be viewed with suspicion. In addition to inspection of the thorax, a thorough search for enlarged nodes should be made in the retrocrural region and upper abdomen.

**First-line imaging techniques**

**Chest radiograph**

A plain chest radiograph is usually the first imaging investigation to be performed, and here the appearances of MPM range from normal in early disease to complete opacification of a hemithorax. These findings depend on the differing amounts of pleural thickening and fluid. A review of 4710 cases showed that a pleural effusion is usually present on the initial radiograph. The mediastinum can be central or it can be displaced towards or away from the affected hemithorax. The pleural thickening can manifest as discrete pleural nodules or can progressively encase the lung. Pleural masses may be visible, often after drainage of the effusion. Rib destruction or pneumothorax may occasionally be seen. Right-sided tumours are more common, accounting for approximately 60% of MPM. The differential for the plain chest radiograph appearances of MPM includes unilateral diffuse pleural thickening; this is more commonly bilateral and relatively symmetrical. An unexplained unilateral pleural effusion or pleural thickening warrants further investigation with contrast-enhanced CT.

**Ultrasound**

Ultrasound (US) can be very useful in identifying pathology of the pleura. The presence of a pleural effusion acts as an acoustic window and can enable the detection of intrapleural and intrapulmonary processes. Pleural effusions and thickening can be readily appreciated by US, and discrete malignant nodules may be seen. US-guided biopsy of pleural thickening and drainage of effusions are well-established, safe techniques.

**Computed tomography**

Contrast-enhanced CT is the primary imaging method for the evaluation of MPM. Malignant or inflammatory pleural disease enhances strongly, and the contrast enables differentiation between thickened pleura, effusion and underlying aerated or collapsed lung. With modern multidetector CT (MDCT), imaging of the entire chest can be completed in under 10 s. The use of narrow collimation of less than 1 mm in thickness allows the final images to be visualized in any plane. Coronal and sagittal reconstructions are particularly useful for assessing chest wall or subdiaphragmatic invasion. In cancer staging, the thorax is normally scanned in the arterial phase. With a delay of 20 to 60 s, pleural thickening can be distinguished from pleural fluid. However, it is our experience that pleural enhancement is more delayed than parenchymal lung enhancement, and with suspected malignant pleural disease there is a case for scanning in a more delayed phase at 45 s.

CT makes possible a detailed evaluation of the pleura and differentiation of benign from malignant pleural disease. Leung et al. studied 74 consecutive patients with diffuse pleural disease. CT features used to distinguish malignant from benign pleural disease included circumferential pleural thickening, nodular pleural thickening, parietal pleural thickening greater than 1 cm and mediastinal pleural involvement. The specificities of these findings were 100%, 94%, 94% and 88%, respectively. The sensitivities were 41%, 51%, 36% and 56%, respectively. Whereas the positive predictive value of these signs is high, the absence of the various signs does not exclude a diagnosis of MPM or metastatic pleural adenocarcinoma. Using these criteria, Traill et al. studied 40 consecutive patients; contrast-enhanced CT correctly identified
28/32 cases of malignant disease and all 8 cases of benign disease, giving a sensitivity of 84% and a specificity of 100% for the technique. This study found circumferential thickening a less reliable indicator for malignancy, and this was observed in the benign and malignant groups equally. Metintas et al. 15 studied the CT features of benign and malignant pleural disease in 215 cases, and confirmed high specificities for circumferential pleural thickening, nodularity and mediastinal pleural involvement, with a 64% specificity for pleural thickening greater than 1 cm.

It is important in cases of suspected pleural malignancy to differentiate between MPM and other pleural malignancy, because the prognosis, treatment and compensation issues are very different. Differentiation would include a full clinical history and examination, and there are certain imaging features which, when used in combination with the clinical findings, are suggestive of MPM. Metintas et al. 15 reviewed the CT findings in 215 cases, 99 of MPM, 39 of metastatic pleural disease and 77 of benign pleural disease. In cases of MPM, the most common CT features were circumferential nodular lung encasement, pleural thickening with irregular pleuropulmonary margins and pleural thickening with superimposed nodules (Fig. 1). In 70% of cases of MPM, there was rind-like extension of tumour on the pleural surfaces.

On multivariate analysis, the CT findings of rind-like pleural involvement, mediastinal pleural involvement and pleural thickness >1 cm were independent findings in differentiating MPM from other malignant pleural disease, with sensitivity/ specificity values of 0.7/0.85, 0.85/0.67 and 0.59/0.82, respectively.

A definitive diagnosis of MPM normally requires cytological or histological sampling, but CT findings may be important for patients with poor performance status, who do not want or are not fit for any invasive biopsy procedures. There can be contraction of the affected hemithorax with associated ipsilateral mediastinal shift, narrowed intercostal spaces and elevation of the ipsilateral hemidiaphragm. Contralateral mediastinal shift is usually due to large effusions (Table 1). 16–19 CT evidence of distant metastases is rare at presentation and may indicate metastatic pleural disease. Pleural plaques are found at CT in approximately 20% of cases of MPM (Fig. 1) and there may be other features of asbestos exposure. Asbestosis, however, is rare in the presence of mesothelioma. 17

MPM is locally aggressive; chest wall involvement is commonly seen at the site of previous intervention, including biopsy, drain and surgical sites. 20 There should be careful evaluation of these areas, and they may be marked with a suitable radio-opaque marker to aid this. Chest wall involvement may manifest as obliteration of extrapleural fat planes, invasion of intercostal muscles, displacement of ribs or bone destruction (Fig. 2). Direct extension of tumour into the major vessels and mediastinum may occur, and is usually manifested as a soft-tissue mass surrounding more than 50% of the structure. 21,22 MPM can invade the pericardium and may be seen at CT as nodular pericardial thickening or pericardial effusion (Fig. 3). The diaphragm does not form a continuous barrier between the pleural and peritoneal cavities, and difficulties can arise in deciding whether the tumour has actually invaded the peritoneum, particularly around the costophrenic angles. 23 Detection of diaphragmatic invasion has proved difficult on single-slice axial CT; the most reliable sign is a soft-tissue mass encasing the diaphragm. A smooth diaphragmatic contour and a clear fat plane between the inferior surface of the diaphragm and the adjacent abdominal organs suggest that tumour does not extend through the diaphragm. 21 However, axial CT has limited sensitivity and specificity in detecting these features, and at our centre we always reconstruct images in the coronal and sagittal planes (Fig. 4). MRI has hitherto had an advantage in view of its superior tissue contrast and multiplanar capability; however, the latter function is likely to be superseded by MDCT.

**Image-guided biopsy**

Pleural fluid cytology has a low sensitivity (26% to 32%) for diagnosis of MPM, 23,24 and reliable
pathological diagnosis requires histological sampling. Historically, the standard technique for pleural biopsy has been to use a reverse-bevelled needle such as the Abrams’ needle. Even in experienced hands, Abrams’ biopsy has a sensitivity of only 55%, probably because of the patchy distribution of MPM and its predilection for the basal and diaphragmatic pleural surfaces.

Image-guided pleural biopsy can be performed as a day-case procedure. Several studies have assessed both CT- and US-guided pleural biopsies, with sensitivities of 86% to 93%, specificities of 100% and a low (3%) complication rate. US-guided pleural biopsy has a sensitivity of 77% and a specificity of 88% for the diagnosis of MPM, with minor complications only. It seems that 18G or 14G needle gauge has little effect on diagnostic accuracy. Maskell et al. randomized 50 patients with suspected malignant pleural effusions to have either a standard Abrams’ needle pleural biopsy or CT-guided biopsy. For diagnosis of mesothelioma, CT-guided biopsy has a sensitivity of 88% versus 55% for Abrams’ biopsy. CT-biopsy as the initial procedure would have averted a repeat biopsy in 40% of patients. By performing core-needle biopsy along the line of the pleura, samples can be taken from pleural thickening as little as 2 mm thick. However, angled biopsies of the pleura may create confusing histology, as the presence of mesothelial cells deep to the pleural surface, a sign of malignancy, may be a result of the angle at which the biopsy has been taken. Tumour seeding along the track has been reported in up to 22% of cases, and post-procedure pneumothorax rates are as high as 3%.

Table 1  CT features of malignant pleural mesothelioma.

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<tr>
<th>Common features</th>
<th>Uncommon features</th>
<th>Distinctive features*</th>
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<tr>
<td>Irregular/nodular pleural thickening</td>
<td>Discrete pleural nodules or masses</td>
<td>Rind-like pleural involvement</td>
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<td>Rind-like pleural thickening</td>
<td>Rib destruction</td>
<td>Mediastinal pleural involvement</td>
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<td>Pleural effusion</td>
<td>Vertebral body erosion</td>
<td>Pleural thickness &gt; 1 cm</td>
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<td>Mediastinal pleural thickening</td>
<td>Mediastinal invasion</td>
<td>Pleural plaques</td>
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<td>Interlobar fissural involvement</td>
<td>Diaphragmatic invasion</td>
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<td>Volume contraction</td>
<td>Chest wall invasion</td>
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* These features distinguish malignant pleural mesothelioma from other pleural malignancies.

Figure 2  (a) Axial contrast-enhanced CT, (b) reconstructed in the coronal plane, shows an advanced right-sided malignant pleural mesothelioma. Note multifocal chest wall (arrows) and subdiaphragmatic invasion.

Figure 3  Axial contrast-enhanced MDCT. The pericardium is thickened, but there is no deep pericardial invasion (IMIG T4). This was confirmed at operation.
provide information about metabolically active areas and, when findings are correlated with anatomical imaging information, PET may be used to help determine the most appropriate biopsy site for obtaining positive results. This is particularly useful in cases with an initial suspected false-negative result.

A prospective multicentre trial comparing cutting-needle percutaneous image-guided biopsy and thoracoscopic biopsy would help clarify the potential advantages and cost-effectiveness of each sampling technique.

### Additional imaging techniques

#### Positron emission tomography

F-18 fluorodeoxyglucose positron emission tomography (FDG PET) may be a useful problem-solving tool in differentiating benign from malignant pleural disease, with a sensitivity for detecting malignancy of 96.8% and a specificity of 88.5% in 63 cases (Fig. 5), and appears to confirm malignant pleural disease which cannot be identified at CT. In a prospective study, Kramer et al. studied 32 patients, 19 with malignant and 13 with benign disease, and found that FDG PET had a high negative predictive value of 92%. FDG PET imaging showed an absence of FDG uptake, and correctly classified 31/35 benign lesions. False-positive results were seen in cases of parapneumonic effusion and tuberculous and uraemic pleural disease.

The standardized uptake value (SUV) is used as a semi-quantitative measure of the metabolic activity of a lesion. However, there is no consensus as to the time point at which to image MPM. The SUV is significantly higher in MPM than in benign pleural diseases such as inflammatory pleuritis and as 9.5%, but it seems rates are lower in the presence of a pleural effusion.

Thoracoscopic biopsy has the advantage of direct visualization of the pleura but, for this technique, the visceral and parietal pleura must not be adherent. In a prospective study of 188 patients with suspected MPM, thoracoscopic biopsy was compared with pleural fluid cytology and Abram’s needle biopsy. Thoracoscopic biopsy yielded sensitivities of 98.4% versus 38.7% for combined pleural fluid cytology and Abrams’ biopsy. Seeding along the biopsy track can occur in up to 50% of such cases.

FDG positron emission tomography (PET) can

**Figure 4** Contrast-enhanced CT shows infradiaphragmatic invasion. (a) Axial view: The diaphragm has been invaded by tumour, with loss of the fat plane between diaphragm and liver and flattening of the superior surface of the liver. This is much more clearly appreciated on (b) the coronal reconstruction.

**Figure 5** CT-PET showing (from left to right) coronal CT, PET and fused images of a left-sided malignant pleural mesothelioma. No evidence of contralateral disease or metastasis is seen.
asbestos-related pleural plaques. However, some MPMs are low-grade tumours and may not be intensely hypermetabolic on FDG PET. There is dispute as to whether the SUV correlates with T stage, but the SUV appears to be higher in cases of nodal and metastatic disease and is associated with an unfavourable prognosis. The SUV does not appear to be related to histological grade. Caution should be taken with patients who have previously undergone talc pleurodesis, as the inflammatory process caused by this procedure can cause a false-positive result. Correlation with CT is needed to demonstrate the high-attenuation pleural thickening due to talc administration.

Areas of pleural thickening may not necessarily correspond to areas of high metabolic activity, and the most appropriate biopsy site may not be apparent from CT results. Metastases are a common finding at post-mortem, and FDG PET may have a role in detecting occult metastases before consideration for surgery.

The combination of PET and CT in PET-CT scanners opens up the possibility of performing diagnostic CT and FDG PET in order to assess the patient at one visit, or of undertaking a low-quality CT and using this to register to an earlier diagnostic CT. Potential problems relate to image registration, which may not be accurate because of respiratory motion and differences between the two imaging methods. It is also possible that FDG is not the optimum tracer, and that one of the other tracers may be more suitable for imaging. This, however, remains to be seen.

**Magnetic resonance imaging**

Relative to adjacent chest wall muscle, MPM is typically isotense or slightly hyperintense on T1-weighted images and moderately hyperintense on proton density and T2-weighted images. MPM enhances avidly with use of gadolinium-based contrast material. Anatomical and morphological magnetic resonance imaging (MRI) features similar to those seen at CT are used to establish local invasion of MPM. For patients being assessed for surgery, MRI can provide additional staging information. In a comparative study of MRI and CT, Knuutila et al. found that contrast-enhanced MRI was superior in demonstrating focal thickening and enhancement of interlobar fissures, which are useful signs in the detection of early malignant pleural disease. On the other hand, enhancement may be seen following pleurodesis of a benign effusion.

Hierholzer et al. retrospectively studied 42 patients and compared CT with MRI. High signal intensity in relation to intercostal muscles on T2-weighted or contrast-enhanced T1-weighted images or both was significantly suggestive of malignant disease. Using morphological features in combination with the signal intensity features, MRI showed a sensitivity of 100% and a specificity of 93% in the detection of pleural malignancy and was thought superior to CT, particularly in detecting chest wall and diaphragmatic invasion (Fig. 6). However, MDCT can now provide 3D images.

MRI is most useful in evaluating patients with questionable areas of local tumour extension at CT, or patients for whom intravenous administration of iodinated contrast material is contraindicated.
Stewart et al.\textsuperscript{42} found that 17/76 patients who were potential surgical candidates by CT criteria had unresectable disease on MRI.

### Staging and resectability

The TNM staging system proposed by the International Mesothelioma Interest Group is used for patients with potentially resectable disease.\textsuperscript{43} Emphasis is placed on criteria for determining the extent of local tumour and lymph node involvement, both of which affect overall survival. Patients with T1 to T3 disease are potential surgical candidates but may not necessarily be cured. The staging system was designed as a surgical tool, and may not be completely applicable to imaging. In practical terms, detection on CT of deep myocardial invasion, multifocal chest wall invasion or sub-diaphragmatic extension is a contraindication to surgery.

### Limitations of cross-sectional and functional imaging in staging and determining resectability

Imaging has a tendency to understage the extent of MPM, which is crucial in determining which cases are potentially suitable for resection (i.e., in distinguishing T3 from T4 disease). Rusch et al.\textsuperscript{44} followed 20 patients who underwent thoracotomy. CT missed chest wall invasion in 7/18 cases, was falsely positive in 2 cases and was also poor at detecting involvement of the diaphragm. Heelan et al.\textsuperscript{45} studied 65 patients who underwent CT, MR and resection of MPM. They found that CT and MR overall showed fairly similar accuracies for staging MPM, i.e. between 50% and 65%. Both techniques had limited accuracies for detecting T1 and nodal disease, but MR was superior to CT for detecting T2 disease (invasion of diaphragm and endothoracic fascia). A more recent study by Patz et al.\textsuperscript{21} suggested that CT and MR were sensitive in predicting resectability, but the statistics may have been skewed by the study population. This problem may be solved with multidetector CT. In a study comparing MRI and surgical stage, MRI understaged 50% of tumours, primarily because of understaging pericardial involvement, although this may not have a significant effect on prognosis.\textsuperscript{42} Because of its poor spatial resolution, FDG PET is unsuitable\textsuperscript{35} for defining T status; the data take a significant time to acquire and images are prone to movement artefact, which may be problematic when pleura measuring only a few millimetres in thickness is being imaged. PET should therefore not be used as a tool for determining resectability.

Mediastinal nodes are commonly involved with tumour\textsuperscript{46} and, as with staging lung cancer, CT has limited accuracy for detecting this; sensitivity is 60% and specificity 70%. Involved nodes may not be enlarged, and ipsilateral mediastinal nodes are often obscured by irregular pleural thickening along the mediastinal border. FDG PET appears to be relatively poor at defining mediastinal nodal metastasis (N2 disease) from adjacent mediastinal pleural involvement. In a study by Flores et al.,\textsuperscript{35} FDG PET missed mediastinal nodal metastases in 8/9 patients, although a high SUV seemed to correlate with the presence of N2 disease. Reliable detection of nodes by PET may be particularly difficult if there is very nodular pleural disease adjacent to the potentially involved nodes in the internal mammary chain and mediastinal groups.

Sugarbaker et al.\textsuperscript{47} found that patients with negative extrapleural (i.e., N2 or N3) nodes had significantly better survival (42% at 2 years) than those whose nodes were involved (23% at 2 years). Routine mediastinoscopy may have a role, but how this is performed and which stations are sampled has not been fully studied.\textsuperscript{46,48} The procedure targets only limited nodes, which may not be those involved in MPM. Even surgical dissection at operation does not evaluate all N3 nodes (or occult metastases). However, FDG PET may have a role in detecting N3 or M1 disease, and PET-CT appears to be a promising technique. However, there are no published studies of its use in MPM at present.

### Treatment options

#### Radical surgery

Extrapleural pneumonectomy entails removal of the lung and all the parietal pleura, pericardium and diaphragm on the affected side. It usually forms part of trimodality treatment, combined with preoperative and postoperative chemotherapy and radiotherapy. In selected patients, 5-year survival can reach nearly 50%.\textsuperscript{49} A large prospective trial over the next 8 years, the Mesothelioma and Radical Surgery (MARS) trial, aims to determine whether radical surgery alters prognosis. Results will therefore be available in time for the peak of the epidemic.

#### Postoperative appearances following radical surgery

The chest radiograph findings after extrapleural
pneumonectomy are often indistinguishable from those of a standard pneumonectomy, although the fluid accumulates more rapidly within the post-pneumonectomy space, i.e. over several days rather than weeks.\(^5^0\) CT or MRI shows a rim of fibrous tissue lining the pneumonectomy space (Fig. 7). This should not be confused with recurrent disease; it is a few millimetres thick and uniform.

Complications, which are similar to those of a standard pneumonectomy, may be first suspected radiologically and include bronchial stump fistula, where there is failure of the pneumonectomy space to fill with fluid. The diaphragm is normally removed and replaced by a synthetic patch\(^5^1\) which is susceptible to rupture, particularly on the left. This may manifest on the postoperative chest radiograph as sudden elevation of the “neo-diaphragm”, with findings confirmed easily by CT. This is important to recognize and indicates immediate surgery. As part of the extrapleural pneumonectomy, some of the pericardium is removed, which can potentially lead to the rare complication of cardiac volvulus. A pericardial patch is normally inserted to prevent this complication. It is likely, as with non-small-cell lung cancer, that if FDG PET were positive preoperatively in this patient group, recurrence could be identified early within the hemithorax from which the lung had been resected. However, this has not been demonstrated in any studies to date.

Assessing response to chemotherapy

Reduction in tumour size is now widely accepted as evidence of tumour response, and the effectiveness of treatment cannot be assessed without robust mechanisms of tumour measurement. The World Health Organization (WHO) introduced measurement criteria in 1979.\(^5^2\) However, it became apparent that tumour measurement using WHO criteria was very laborious. The response evaluation criteria in solid tumours (RECIST) were proposed and validated in 2000.\(^5^3\) RECIST is based on the assumption that tumours are generally spherical, and that a maximal unidimensional measurement correlates well with an overall reduction in tumour size. MPM tends to grow as a rind around the chest wall, and changes in tumour bulk tend to manifest as changes in tumour thickness perpendicular to the chest wall, rather than the maximal tumour dimension. RECIST therefore cannot be applied easily, and MPM was not included in the initial studies. Studies have shown discrepancies between tumour measurement in MPM using the WHO and RECIST criteria.\(^5^4\) These can occur in up to 47% of cases, in which the majority of cases were underscored by RECIST. Disease progression also was underscored by RECIST in 24% of cases.\(^5^5\)

Tumour bulk may in some cases consist of mainly fibrous tissue, which often shows little immediate change in size, even if the sparse tumour cells within it have responded to treatment. Fibrosis can lead to shrinkage of the affected hemithorax, making it difficult to find the same measurement points on subsequent examination.\(^2^3\) Difficulties also arise for patients who have undergone pleurodesis, as they have residual pleural thickening even in the absence of active disease (Fig. 8). Byrne et al.\(^5^6\) have validated modified RECIST criteria for assessing response of MPM to chemotherapy in 73 cases. They made two measurements of tumour thickness perpendicular to the chest wall at three separate reproducible anatomical levels within the chest. The sum of the six measurements provides a “pleural unidimensional measurement”. Other bidimensionally measurable lesions were measured as per RECIST and added to the pleural unidimensional measurement. The percentage change in measurements between scans was as for RECIST. Changes in forced vital capacity, a surrogate marker for patient well-being, also correlated well with changes in tumour measurement.

In the future, computer-assisted techniques for
measurement of MPM may play a role in assessing tumour response. The RECIST criteria are limited in all tumour groups, since size change is slow and metabolic change should be rapid. Carretta et al. observed a reduction in FDG uptake in a small number of cases with MPM following chemotherapy. Choosing when to scan following chemotherapy, and the timing of the scan following the injection of FDG, are likely to be crucial to this assessment. It is, however, likely that this change in metabolic activity would precede any change in volume, and would also be easier to assess than a change in tumour bulk in malignancies such as mesothelioma.

Conclusions

MPM is a disease with an increasing incidence, and radiologists and clinicians will be seeing patients with the disease well into the 21st century. MPM behaves quite differently from lung cancer, and there are many difficulties in TNM staging and assessing response to chemotherapy. There is a need for a more practical, radiology-friendly staging system, as the majority of patients do not undergo radical surgery. CT-PET may hold the key to more accurate assessment, by providing further information on anatomy and metabolic function.

References


Figure 8 Malignant pleural mesothelioma before and after pleurodesis. (a) Contrast-enhanced axial MDCT shows minor right-sided pleural thickening. (b) Following pleurodesis, the pleura is thicker and there has been volume loss within the right hemithorax. These appearances pose challenges when trying to assess response to chemotherapy.


55. Van Klaveren RJ, Aerts JGJV, De Bruin H, et al. Inadequacy of