

State-of-the-art: Radiological Investigation of Pleural Disease

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Abbreviations:

- CT: Computed Tomography
- CXR: Chest radiography
- DCEMRI: Dynamic contrast-enhanced MRI
- DWI: Diffusion-Weighted Imaging (MRI sequence)
- MRI: Magnetic Resonance Imaging
- PE: Pulmonary Embolism
- PET: Positron Emission Tomography
- STIR: Short Tau Inversion Recovery (MRI sequence)
- US: Ultrasound

Abstract (196 words, limit 200)

Pleural disease is common. Radiological investigation of pleural effusion, thickening, masses, and pneumothorax is key in diagnosing and determining management. Conventional chest radiograph (CXR) remains as the initial investigation of choice for patients with suspected pleural disease. When abnormalities are detected, thoracic ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET) can each play important roles in further investigation, but appropriate modality selection is critical.

US adds significant value in the identification of pleural fluid and pleural nodularity, guiding pleural procedures and, increasingly, as “point of care” assessment for pneumothorax, but is highly operator dependent. CT scan is the modality of choice for further assessment of pleural disease: Characterising pleural thickening, some pleural effusions and demonstration of homogeneity of pleural masses and areas of fatty attenuation or calcification. MRI has specific utility for soft tissue abnormalities and may have a role for younger patients requiring follow-up serial imaging. MRI and PET/CT may provide additional information in malignant pleural disease regarding prognosis and response to therapy.

This article summarises existing techniques, highlighting the benefits and applications of these different imaging modalities and provides an up to date review of the evidence.

Main Text:

Introduction/Background

Pleural disease is common, affecting over 300 people per 100,000 population each year[1]. Radiological investigation of pleural effusion, thickening, masses, and pneumothorax is key in establishing a diagnosis, as well as initial and ongoing management.

Chest radiography (CXR) is still the accepted initial modality for the investigation of pleural disease. When abnormalities are detected, thoracic ultrasound, computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET) can each play important roles in further investigation, but appropriate modality selection is critical.

This article summarises existing techniques, highlighting the benefits and applications of these different imaging modalities and provides an up to date review of the evidence.

Technique

Chest Radiography

An erect posterior-anterior CXR should be performed wherever possible. Previously, lateral CXR were used to demonstrate small effusions, but in many countries by this has been superseded the widespread use of US and CT imaging. Supine CXR are less useful than erect CXR in the detection of air or fluid, as air will be dispersed anteriorly and fluid posteriorly.

Ultrasound

Ultrasound (US) is frequently used to assess pleural disease detected on CXR. Its portability and ease of use allows US to be performed on patients as outpatients or inpatients (including critically unwell patients in intensive care who may not be suitable for an erect CXR). Use of US is now mandated in pleural procedures investigating pleural fluid: pleural aspiration or chest drain insertion [2, 3]. 3.5-5.0MHz sector transducer probes are the most commonly used as they provide good depth penetration to fully visual effusions in larger patients, whilst still allowing good spatial resolution at low depth to aid interventional procedures. The use of US requires training to effectively record quality images and correctly identify pleural disease. Therefore, US can be highly operator dependent with some features, such as diffuse pleural thickening and pneumothorax, requiring experience to interpret.

Computed Tomography (CT)

CT investigation of pleural disease should involve multi-slice thin sections (0.5-2.0mm) to enable multi-planar reconstruction. Volumetric data acquisition with multi-slice CT allows

easy access to isotropic 3-D reformatting. Images should be reviewed using mediastinal window setting (40/400) on a soft-tissue algorithm but supplemented by review of the fissures using lung windows (-500/1500). Ideally, intravenous contrast should be administered, with a delay of 60-90 seconds ("pleural phase") to allow maximum pleural soft tissue enhancement[4] A significant proportion patients presenting with unilateral effusion may incidentally have a pulmonary embolism (PE), particularly those subsequently diagnosed with pleural malignancy[5]. A single scan with delayed acquisition could provide contrast scan could provide information on pleural disease and potential embolism by enhancing the pleura and the major vessels[6].

PET/CT

The combination of Positron Emission Tomography (PET) and CT scanning allows the visualisation of metabolically active tissue, by increased uptake of a radiolabelled glucose isotope. At present the only commercial radioisotope available is 18-Fluorodeoxyglucose (FDG). Malignant cells are usually more metabolically active than non-malignant cells and therefore concentrate FDG more avidly than normal tissue. The limitations to increased clinical usage of PET continue to be cost, availability and length of examination time.

MRI

Magnetic resonance imaging (MRI) has a limited role in the investigation of pleural disease because of movement artefact and poor spatial resolution. Respiratory and cardiac gating should be used routinely[7, 8]. A body coil is used initially to obtain field-of-view scout images. Specialised coils can then be used if further specific images are required. Typical sequences used to image the chest are T1-weighted spin echo, proton-density and T2-weighted spin echo or fast spin echo with fat saturation, and short tau inversion recovery (STIR). T1-weighted images are good for anatomy and demonstrate excellent contrast between abnormalities in the pleural space and extrapleural fat[9]. T2-weighted images clearly highlight pleural fluid and provide good contrast between tumour and muscle[9]. Dynamic contrast-enhanced MRI (DCEMRI) and Diffusion-Weighted Imaging (DWI) can be used to assess malignant pleural vascularity and predict response to chemotherapy in patients with mesothelioma[10, 11].

Normal appearance

CXR

On standard CXR, the normal parietal and visceral pleura are not visualised, except where the visceral pleural invaginates into the lung to form the fissures e.g. the oblique and horizontal fissures seen when they are tangential to the X-ray beam.

US

The normal pleura are seen as a bright echogenic line, known as the “pleural stripe” comprising of the parietal and visceral pleura (Figure 1). This occurs as the majority of the acoustic energy of the US beam is reflected by the air in the lung up to the visceral pleural. Distal to the pleural stripe, artefacts known as “comet tails” (or “B lines”) appear as vertical echogenic bands extending into the image. Comet tails are produced by any small highly reflective object in the scanning plane and may be caused by small foreign bodies, foci of calcification and discrete air collections[12]. During normal respiration the pleural stripe appears to shimmer as inhomogeneities move at the pleural interface, known as “lung sliding”. Comet tails and lung sliding signs disappear in the presence of pneumothorax.

CT

In the normal patient, the thin visceral pleura and parietal pleura (along costal and mediastinal surfaces) are not visualised on CT imaging. However, on HRCT, a thin layer of extrapleural fat separates the pleura from the fascia along the costal pleural surface adjacent to the parietal pleura, giving rise to the 1-2mm “intercostal stripe”[13] (Figure 2). In the absence of disease, there should be no soft tissue internal to the rib or paravertebral region. On multi-slice CT or HRCT, fissures appear as smooth, well defined linear opacities, less than 1mm in thickness[13].

MRI

The normal pleural membranes and fissures are too thin (<1mm) to be visualised on MRI, and can only be identified if thickening or fluid is present.

Pleural Thickening – Benign

Asbestos-related benign pleural disease may be parietal in origin, including pleural plaques (which can be extensive), or diffuse visceral pleural thickening.

CXR

On CXR, diffuse pleural thickening is seen as smooth, continuous pleural density extending over at least 25% of the chest wall. This can be a subtle increase in radiographic density laterally on CXR, and often includes blunting of the costophrenic angle[14] (Figure 3). The American Thoracic Society differentiates diffuse pleural thickening from extensive pleural plaque disease (which can produce similar appearance) by the presence of blunting of the costophrenic angle to diagnose diffuse thickening[15].

US

Pleural thickening can generally only be seen once >1cm in depth[16]. Thickening can be echogenic or echo-poor. Identification can be difficult in the absence of pleural fluid due to lack of contrast between echogenic thickening, extra-pleural fat and the bright lung-pleural

interface. Colour Doppler US can be useful to distinguish between thickening and small loculated effusions, as effusions may show a fluid movement (e.g. with cardiac pulsation).

CT

Pleural plaques commonly occur in the posterolateral aspect of the lower costal, parietal and on the diaphragm, with the characteristic appearance on CT of discrete, elevated lesions with steep rounded or “rolled” edges.[17]. However, pleural plaques often increase in size and number with time, involving other aspects of the parietal pleura and may become extensive, making differentiation from diffuse pleural thickening more difficult. Pleural plaques may also be associated with more subtle changes in the lung parenchyma, appearing as interstitial lines on CT, hence being known as “hairy plaques” (Figure 4A). Diffuse visceral pleural thickening, which may occur in the context of pleural plaques, is defined as “a continuous sheet of pleural thickening >5cm wide, >8cm in craniocaudal extent, and >3mm thick[17]. The edges of diffuse pleural thickening will be tapered (in contrast to pleural plaques)[18], and is usually associated with rounded atelectasis[19]. Rounded atelectasis appears on CT as a rounded mass resulting from the contraction and distortion of the lung (figure 4B) adjacent to chronic pleural thickening of any cause but most commonly associated with asbestos-related pleural disease. The distortion of the lung can be seen as swirling and deviation of vessels and bronchi converging on the mass.

Non-asbestos related benign disease

Diffuse thickening of the pleural membranes, seen on CT as an increase in soft tissue at the lung-pleural interface, will be similar in all causes of benign pleural thickening regardless of the cause. However, associated features on CT scan may give clues as to the initial aetiology: Extensive calcification, volume loss, thickened extra-pleural fat layer and associated parenchymal abnormality may favour prior empyema (particularly tuberculosis), whereas pleural calcification with rib deformity and normal lung parenchyma would indicate previous traumatic haemothorax. The appearance post-talc pleurodesis typically demonstrates a characteristic talc “sandwich” of soft tissue parietal pleural thickening, high attenuation talc and increased soft tissue visceral pleural thickening (figure 5A)[20]. Rarely, late appearance of previous talc pleurodesis can present as a discrete granulomatous lesions[21].

MRI

High resolution MRI is a good technique for assessing pleural plaques and is comparable to CT, although CT is superior in detecting calcification. On T1- and T2-weighted sequences, plaques will be of low signal.

Pleural Thickening – Malignant

CXR

Metastatic disease accounts for the majority of malignant pleural thickening. Primary pleural malignancy (mesothelioma) and metastatic disease appear similar radiologically. Malignant pleural thickening changes are commonly irregular, nodular opacities around the periphery of the lung. These can be associated with pleural effusions in 60%, usually unilateral but 5% may have bilateral disease[22]. Mesothelioma can be associated with volume loss in the affected hemithorax, but this is not specific for malignancy. Calcified or non-calcified pleural plaques may co-exist as evidence of prior asbestos exposure. 20% of patients with mesothelioma will have radiographic evidence of interstitial disease or asbestosis[22].

US

Although benign diffuse pleural thickening alone can be difficult to visualise on US, in the presence of a pleural effusion, pleural nodularity (parietal, visceral or diaphragmatic) are diagnostic of pleural malignancy[23].

CT

The classically described features of malignant disease on CT scanning are: nodular pleural thickening, mediastinal pleural thickening, parietal pleural thickening (>1 cm) and circumferential pleural thickening(Figure 6)[24]. These four features are said to have a high specificities: 87-100%, 68-97%, 64-98% and 63-100%, but low sensitivities: 18-53%, 14-74%, 7-47% and 7-54%, respectively [24-30]. The presence of circumferential pleural thickening in the presence of pleural fluid is less specific for malignancy[27]. In addition, a more recent study, assessing the “real world” utility of CT scanning patients being investigated for malignancy, reported the overall sensitivity and specificity of CT scans reported as “malignant” as 68% and 78%, respectively. The positive predictive value of a malignant CT report was 80% with a negative predictive value of only 65% [31]. This suggests that, although sensitivity of a malignant CT report is higher than previously reported, the specificity was significantly lower. Caution is advocated in relying on negative CT scans when investigating patients with suspected malignancy – in practice, when a CT suggests lack of malignant features, the patient will not have malignancy in only 65% of cases[32]. By contrast a scoring system for patients being investigated for undiagnosed pleural effusions, based upon thoracic (e.g. pleural nodularity) and non-thoracic findings (e.g liver metastasis or abdominal masses) on CT scan gave a sensitivity of 88% and specificity of 94% for malignancy[33]. Chest wall invasion and rib destruction at multiple sites are good indicators of malignancy.

In patients being investigated for potential pleural malignancy with pleural effusion, there is no evidence that draining the pleural fluid prior to CXR or CT scan provides any additional information to imaging performed in the presence of fluid[34]. Indeed, leaving some pleural fluid may be beneficial in identifying pleural abnormalities and will facilitate further diagnostic procedures (e.g. US-guided biopsy or medical thoracoscopy) if required.

PET/CT

Positron Emission Tomography (PET) and PET/CT is increasingly used as a non-invasive method of determining metastatic spread in cancer patients. In addition PET/CT has been proposed as an imaging technique to allow differentiation between benign and malignant pleural disease (figure 7). A number of small prospective and retrospective studies have reported differing sensitivities (88-100%) and specificities (35-100%)[35]. More recently, three meta-analyses were published on the diagnostic accuracy of PET and PET/CT in the differentiation of malignant and benign pleural lesions and effusions. Two were performed by Treglia et al. The first, in patients with pleural lesions without known cancer diagnoses found a sensitivity of 95% and a specificity of 82% [36]. The second meta-analysis included patients with known cancer (90% lung cancer) and reported a lower sensitivity of 86% but similar specificity of 82% [37]. It is unclear how this distinction benefits the analysis or the clinician. The third meta-analysis subdivided their analyses into those using PET or PET/CT and qualitative/visual readings or semi quantitative readings (by means of SUV or comparison of two time points during acquisition)[38]. The visual or qualitative methods provided high sensitivity (91%) but low specificity (67%). Use of semi-quantitative readings only marginally increases specificity (74%) at the detriment of sensitivity (81%). Therefore, clinicians should be mindful of the potential false-negative and false-positive findings. False positives include infection (e.g. pleural tuberculosis) or previous pleurodesis with talc; false negative could include low grade (and hence low metabolic activity) epithelioid mesothelioma. As such, PET/CT does not appear to add additional diagnostic value beyond CT scanning for differentiating benign and malignant disease at this time. PET/CT should be avoided in patients who have previously received talc pleurodesis as PET will be highly avid regardless of underlying of disease (Figure 5B).

PET/CT may be of use in determining prognosis and assessing response to chemotherapy [39]. Tumours with low SUV (standardised uptake value) are more likely to be epithelioid and to have a better prognosis. A reduction in metabolic activity after chemotherapy (as measured by SUV, metabolic tumour volume or total glycolytic volume) appears to correlate with increased time to progression and longer survival [40]. However, this application is only being used in the context of clinical trials at present. PET/CT may also have a role in identifying the optimal site for radiologically-guided pleural biopsy for potential pleural malignancy, which is being assessed in a currently recruiting study in the UK.

Apical pleural thickening (or “pleural cap”) is often idiopathic and increases in frequency with age. If associated with prior tuberculosis, CT will demonstrate an increase in apical pleural fat. However, it is important to distinguish benign pleural capping from Pancoast tumour. Malignant thickening is usually thicker and asymmetrical, and may be associated with bony destruction. PET/CT can provide additional assistance in distinguishing either residual disease or tumour relapse in an area of apical pleural thickening post-radiotherapy.

MRI

Although CT is the imaging method of choice for investigating potential pleural malignancy, MRI may be of some additional value in differentiating benign from malignant disease[7]. One study showed low-intensity pleural signal relative to intercostal muscle to be useful in predicting benign disease[41]. Contrast-enhanced fat-saturated T1-weighted sequences may be useful in assessing focal thickening and interlobular fissures. Diffusion-weighted imaging (DWI) shows promise in differentiating benign from malignant disease, with malignant tissue being more structured and compact than benign. The characteristic difference in signal results in a hyperintense speckled appearance which is being coined “pointillism”. A recent suggests this technique has a sensitivity of 93% and specificity of 79% in the diagnosis of malignant pleural disease (mainly mesothelioma)[11].

Pleural Fluid (including Empyema)

CXR

Pleural fluid on erect CXR appears as a blunting of the costophrenic angle and a flattening of the diaphragm. These signs are only evident if there is approximately 200ml or more, CXR can appear normal with up to 500ml[42]. As the volume of fluid increases, the characteristic “meniscus” sign is seen on CXR (Figure 8A). Complete (or near complete) opacification of the hemi-thorax occurs in massive effusions. Mediastinal shift may be evident, although is absent or less-apparent if there is associated ipsilateral pulmonary collapse. Large effusions can invert the hemi-diaphragm, particularly on the left as the liver splints the diaphragm on the right.

Loculated effusions, such as may occur in the context of empyema or haemothorax, do not move freely in the pleural space due to adhesions between the visceral and parietal pleura. Therefore, the fluid does not always appear in dependent areas and often has a sharp medial margin and hazy lateral margin(Figure 8B) [43].

US

Ultrasound (US) is the most frequently performed radiological investigation to evaluate effusions detected on CXR. It can easily confirm the presence of an effusion, assess its character and is essential to guide pleural intervention[2, 3]. Pleural fluid is hypoechoic, appearing dark on US, often with an echogenic line of visceral pleura visible distally. Echogenic effusions are always exudates, but anechoic effusions can be either transudates or exudates[23]. Exudative effusions (with high protein content) often form septations with the deposition of fibrin strands becoming thicker over time (Figure 9A). They are associated with infected or malignant effusion, but can occur in an exudative effusion of any cause. Eventually, septations may be thick and profuse enough to give a honeycomb-like appearance (Figure 9B). Patients with septated pleural effusions have a higher morbidity and mortality compared to those without septations [44].

CT

CT imaging can easily identify pleural fluid, but is not required in the management of the most pleural effusions. However, CT should be considered in those patients with infected pleural fluid (empyema) who are too unwell or unsuitable for US (e.g. in intensive care), or those who demonstrate significant volume loss on the CXR or lobar collapse potentially suggestive of underlying malignancy. As CT scans are performed supine, free-flowing fluid will collect initially in deep lateral and posterior pleural recesses. It may be difficult to distinguish pleural fluid from ascites, particularly in patients with inverted hemidiaphragms. Features to aid distinction include: anterior displacement of the diaphragmatic crus by pleural fluid (the “displaced crus” sign) is not seen in ascites and a sharp interface between fluid and liver or spleen is characteristic of ascites. “Pleural phase” contrast-enhanced CT scans will often enable distinction between small effusions and pleural thickening that may be appear similar on an unenhanced scan.

Empyema (as with an exudative cause of effusion) will demonstrate parietal and visceral pleural enhancement on contrast-enhanced CT scan, resulting in the “split-pleura” sign (Figure 10). However, pleural thickening and enhancement are seen in 86-100% of cases of empyema, compared to 60% of parapneumonic effusions[45]. Increased thickening and attenuation of the extrapleural fat adjacent to the fluid will also be present[45]. CT can be helpful in assessing in patients not responding to conventional treatment of empyema with antibiotics and chest tube drainage. Septations are not as readily seen on CT as US, although multiple pockets of gas (with or without associated air fluid levels) suggest their presence. Loculated pleural collections are often lenticular in shape with smooth margins and relatively homogeneous attenuation[46]. Mediastinal node enlargement (of less than 2cm) is common. However, nodal involvement and increased CT-detected pleural thickening is not predictive of outcome of empyema treatment (e.g. need for surgery)[47].

Differentiating empyema and pulmonary abscesses which abut the pleura can be difficult, but important, because the former require chest tube placement for drainage. On CT, abscesses will often appear as spherical, thick walled lesions with abrupt vessel cut-off and the presence of bronchi at the interface between abscess and normal lung. Abscesses will often make an acute angle with the chest wall, whereas empyema commonly will create an obtuse angle[48].

PET/CT

PET/CT is rarely useful in the context of pleural infection as the effusion will be highlighted as metabolically active and unable to distinguish between that and potential underlying malignancy.

MRI

The role of MRI in imaging pleural effusions is limited due to flow artefacts within the fluid created respiratory and cardiac movement, and the excellence of US and CT. As outlined

above, CT imaging with pleural phase contrast is the optimum modality to assess for malignant pleural effusions. However, if contrast is contra-indicated, MRI can be used to identify chest wall invasion or septations within pleural fluid. T2-weighted images will demonstrate pleural nodularity, in the absence of contrast, as both fluid and extrapleural fat will be high signal in comparison with the low signal pleura.

Pneumothorax

CXR

Pneumothorax is commonly demonstrated on erect CXR alone by visualisation of the visceral pleura (not normally seen) with the absence of parenchymal lung markings and increased radiolucency beyond this line (Figure 11). CXR films should be taken on inspiration. There is little additional benefit in performing additional expiratory films for small pneumothorax detection[49], particularly as CT is a more sensitive modality in these cases. However, in supine films, identification of the “deep sulcus” sign may aid pneumothorax detection: air seen anteromedially and subpulmonary creates a lucent focus adjacent to the diaphragm from cardiophrenic to lateral costophrenic recesses[50]. In cases of suspected tension pneumothorax, decompression should be performed on clinical grounds and should not be delayed by imaging.

US

Sonographic findings of pneumothorax are a lack of lung sliding and comet tails that are seen in the normal patient[12]. M-mode on linear probes can also be used to look for lung sliding. M-mode detects movement over time. In normal patients, lung movement generates the “seashore sign”: lung sliding distal to the pleural line creates a granular pattern (the “sand”) and the static portion proximal to the pleural line creating lines (the “sea”) (Figure 12A). In the presence of pneumothorax, the lack of lung sliding removes the granular pattern and the whole image becomes a series of parallel lines (above and below the pleural line) known as the “stratosphere sign” (Figure 12B)[51]. The “lung point” sign delineating the border between normal sliding lung and pneumothorax can be used to identify and potentially determine the size of pneumothoraces. However, it has high specificity but low sensitivity as it relies on at least part of the lung being in contact with the chest wall and is therefore not seen in large pneumothoraces[52]. Horizontal reverberation artefacts (or “A lines”) appear as equally spaced hyperechoic repetitive lines caused by reflection from the pleura in the presence of pneumothorax and not in normal patients (Figure 12B).

Ultrasound has been reported as more sensitive than CXR in detecting pneumothorax post-lung biopsy [12, 53] and detecting occult traumatic pneumothoraces in emergency departments[54]. US may also be useful in monitoring resolution of pneumothorax during

drainage and identifying residual pneumothorax at follow-up[55]. However, relying on an absence of signs can lead to false positives, particularly in those with limited experience in thoracic ultrasound. Patients with hyperinflation, air trapping, bullous disease (e.g. in chronic obstructive pulmonary disease), or previous pleurodesis can demonstrate similar lack of lung sliding and comet tails[56].

CT

Whilst the majority of pneumothoraces will be identified on standard PA CXR, CT is more sensitive, particularly for small pneumothoraces or when a patient is supine (e.g. trauma studies, figure 13). 25-40% of pneumothoraces post-lung biopsy not detectable on CXR are present on CT[57]. In the context of trauma, CT may also provide important information such as lung contusion, infiltrates or pericardial effusions. In patients with extensive subcutaneous emphysema, consolidation or adult respiratory distress syndrome in intensive care, identification of pneumothorax on CXR can be difficult. In these cases, CT can assist in pneumothorax detection and determining site for chest drain insertion. CT is also useful in drain placement in the context of pneumothorax secondary to severe emphysema (to differential pneumothorax from bullous lung disease).

Rare pleural tumours

Fibromas

CXR

Localised fibrous tumours are small rounded or oval homogeneous masses on CXR. They have a sharply delineated contour and are more commonly seen in the lower half of the chest. Pedunculated tumours may change position with respiration or posture.

CT

On unenhanced CT scan they will appear homogeneous. Calcification is rarely seen. Fibromas will vary in size and larger tumours will displace the lung parenchyma causing atelectasis in adjacent lung, with a smooth tapering margin and characteristically, an obtuse angle at the junction of the mass and the pleura [58]. After intravenous contrast, up to 40% of fibromas will be heterogeneous (figure 14A) [59]. Those with malignant change may show central necrosis on contrast-enhanced CT scan. Fibromas should be identified radiologically as percutaneous biopsies of fibromas with central necrosis have been reported to develop pleural metastases. Larger fibromas will also develop extensive collateral circulation, which, if identified, may require embolisation prior to surgical resection to reduce blood loss.

MRI

Pleural fibromas appear as fibrous tissue masses on MRI with low to intermediate signal on T1- and T2-weighted scans. Heterogeneous areas, including necrosis or haemorrhage will be highlighted as high signal intensity on STIR or T2-weighted images (figure 14B). MR is more often able to show the origin of the mass than CXR or CT scan.

Lipomas and liposarcomas

Lipomas are rare benign pleural tumours, often discovered incidentally as usually asymptomatic. On CT scan, lipomas will appear as uniform pleural masses with the density of fat (<50 Hounsfield Units) and may be associated with linear soft tissue stranding in the lung parenchyma (figure 15) [60]. MRI will also identify a well-defined homogeneous mass, which will be hyperintense on T1- and moderate intensity on T2-weighted images.

Liposarcomas are rare malignant tumours arising from fatty tissue. Unlike lipomas, they tend to produce symptoms of chest pain and, possibly, soft tissue swelling if extending into the intercostal muscle. In contrast to lipomas, CT scan will demonstrate a heterogeneous mass with components of fat, fibrous septae and nodular soft tissue[60]; and MRI will show low signal on T1- and high intensity on T2-weighted images (myxoid degeneration).

Future directions

The use of portable US machines by physicians will continue to increase; not least as a result of formalised training requirements, but as additional areas of value are being identified. US-guided pleural procedures are increasingly being performed by physicians and advanced techniques may provide bedside diagnostic and prognostic information: US assessment of lung entrapment and sliding to determine likely pleurodesis success, or need for intrapleural agents (e.g. fibrinolytics) in pleural infection. Contrast-enhanced US may be able to distinguish benign from malignant pleural disease and potentially guide therapeutic options for patients with malignancy.

PET/CT will continue to advance as radiolabelled tracers for tumour activity and response to therapy become available (e.g. markers of cell proliferation, tumour hypoxia and apoptosis). Dynamic contrast-enhanced MRI (DCEMRI) and Diffusion-weighted imaging (DWI) also show promise in being able to differentiate benign from malignant disease.

Conclusion

Conventional CXR remains as the initial investigation of choice for patients with suspected pleural disease. US adds significant value in the identification of pleural fluid and pleural nodularity, guiding pleural procedures and, increasingly, as “point of care” assessment for pneumothorax, but is highly operator dependent. CT scan is the modality of choice for further assessment of pleural disease: Characterising pleural thickening, some pleural

effusions and demonstration of homogeneity of pleural masses and areas of fatty attenuation or calcification. MRI has specific utility for soft tissue abnormalities and may have a role for younger patients requiring follow-up serial imaging. MRI and PET/CT may provide additional information in malignant pleural disease regarding prognosis and response to therapy.

Text for Figures:

Figure 1: Ultrasound: normal lung with pleural stripe (White Arrow) and “comet tail” artefacts (outlined by small white arrows)

Figure 2: Normal CT with pleural “intercostal stripe” (Arrow)

Figure 3: CXR showing diffuse thickening (arrow) and blunting of costophrenic angle (Right)

Figure 4: A: CT image showing pleural plaques and associated interstitial lines (“hairy plaques”)(Arrows). B: Rounded atelectasis (arrow)

Figure 5: A: CT post-talc on left circumferential nodular pleural thickening involving the mediastinal surface with high density elements (white arrows). B: PET scan demonstrating activity post-talc pleurodesis (black arrow)

Figure 6: Two CT images showing features of malignant disease: nodular thickening (cross)+ mediastinal involvement (arrow), both in the presence of pleural effusion (E)

Figure 7: CT image (A) and PET/CT image (B) highlighting malignant disease (bright red)

Figure 8A: CXR showing pleural effusion (right) with meniscus sign

Figure 8B: CXR showing a loculated pleural effusion (right). Note two distinct pockets (*) with sharply demarcated medial borders (white arrows)

Figure 9A: US showing pleural effusion (F) with early septations (arrows)

Figure 9B: US showing organising pleural effusion with heavy mature septations (arrow)

Figure 10: CT showing empyema and “split pleura” sign: enhancement of the thickened inner visceral pleura (arrow) and outer parietal pleura separated by pleural fluid (E))

Figure 11: CXR showing pneumothorax (left). Arrow demonstrating visible visceral pleural edge

Figure 12A: US images of normal lung: A – 3.5Hz curvilinear probe showing bright pleural line (arrow); B - M-mode “seashore” sign: lung sliding distal to the pleural line creating granular pattern (the “sand”, *) and the static portion proximal to the pleural line creating lines (the “sea” †)

Figure 12b: US images in pneumothorax. A: 3.5Hz curvilinear probe showing bright pleural line and also exaggerated horizontal (A-line) artefacts (arrows); B: M-mode demonstrating the “stratosphere” sign: loss of granular pattern associated with lung movement. Whole image is series of parallel line.

Figure 13: CT image using lung windows showing small left pneumothorax (arrow) in trauma patient

Figure 14A: CT showing large pleural fibroma (*) with heterogeneous pattern post-contrast

Figure 14B: MRI (STIR image) showing large pleural fibroma (*)

Figure 15: CT with contrast showing pleural lipoma (*). A: Using lung windows; B: Using mediastinal windows (Note low density of lipoma)

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