MRI of the thorax – an update

RAD Magazine, 42, 493, 22-24

Edwin J R van Beek
SINAPSE chair of clinical radiology, University of Edinburgh
edwin-vanbeek@ed.ac.uk

Andrew J Swift
Professor of MR physics, University of Sheffield
a.j.swift@sheffield.ac.uk

Jim M Wild
INSIGNEO senior clinical research fellow
University of Sheffield
j.m.wild@sheffield.ac.uk

Introduction
Chest radiology traditionally consists of plain chest x-rays and computed tomography examinations, or so it was a decade ago. New modalities and developments in techniques now require a more comprehensive functional and structural approach to imaging the chest, which should include assessment of all its contents (the term is cardiothoracic radiology) as well as application of PETCT, MRI and, in the future, MRPET. This review addresses the potential clinical indications for MRI, as currently available to most radiology departments, as well as some future directions with clinical potential currently being evaluated in research.

Techniques and hardware
The technical and hardware requirements for chest MRI as well as potential applications were recently covered in a series of articles in Insights into Imaging.1-6 The interested reader will find most details on how to implement MRI of the thorax there, and we will merely summarise the main requirements here.

It is feasible to perform MRI of the thorax on almost any available MRI scanner; most will be performed on 1.5T, while 3.0T scanners are increasingly available in larger teaching hospitals. Chest imaging at 3.0T is possible but it is more challenging and requires some sequence optimisation in order to tackle the challenges presented by magnetic field inhomogeneity in the thorax, especially when imaging protions in the lung parenchyma. Short echo time sequences such as ultra short echo time and short echo time-balanced steady-state free precession and spoiled gradient-echo single-shot spin echo sequences form the basis of the chest imaging MR toolkit in this respect. Receive array coils such as used for cardiac MRI also increase signal to noise and allow parallel imaging for reduction in image acquisition time which assists in keeping the breath-hold time to a clinically acceptable period.

Gadolinium-based contrast
Gadolinium is a very useful contrast agent for imaging the chest. It highlights the vasculature, allows for the study of lung perfusion providing a viable alternative to SPECT and planar scintigraphy in the diagnosis of chronic thromboembolic disease, and is particularly useful to study soft tissue masses, including lung cancer, pleural lesions and chest wall pathology. In almost every indication, contrast-enhanced sequences will be required to fully investigate the patient.

Novel contrast methods
Oxygen-enhanced MR imaging
The 1H signal from blood and tissue in the lung parenchyma can be altered by inhalation of oxygen, which is paramagnetic, and thus changes the T1 of the signal. This provides a means of acquiring images of the lungs which are weighted by lung ventilation and gas exchange, adding some functional sensitivity to standard structural 1H MRI.

Hyperpolarised noble gas MRI
The gases 3He and increasingly 129Xe can be magnetically polarised to give high signal to noise images of lung ventilation and structure-function relationships such as gas exchange and diffusion. This provides a powerful physiological addition to the 1H MRI capability, making it a highly sensitive method for evaluation of novel drug and interventional treatments in a wide range of lung diseases. These novel contrast agents have recently been adopted in diagnostic practice in Sheffield but there are still issues surrounding the scalability and expense of the associated technology, although this is less than the cost of the MRI scanner itself and the UK MRC and NIHR have invested heavily in research to help in the clinical translation of this technology recently.

The future will tell whether these exciting functional techniques will become adopted in diagnostic lung MRI and it may require a step change in the way radiology, medical physics and pulmonary medicine work in a multidisciplinary clinical imaging environment to fully realise their potential.

Indications
There are a number of existing indications where MRI can play a niche (or even more significant) role in the diagnostic management of patients. The main indications will be described here, as well as the potential place within the larger arsenal of diagnostic tools.

Lung cancer
For lung cancer, the routine chest CT protocol will remain the first choice for diagnosis. Staging, which is based on the assessment of patients for potential curative intent, will remain based on PETCT imaging (in conjunction with additional target examinations such as MRI of head or liver).

There are some major areas where MRI has a definitive role. Tumours in the lung apex (Pancoast) are often difficult to depict using CT imaging alone. MRI is superior in demonstrating the various soft tissues and the main structures of interest, including the blood vessels and the brachiocephalic plexus (figure 1). In these tumours, MRI should be a first test of choice for evaluation of surgical/radiotherapy intervention.

Tumours with chest wall involvement similarly may benefit from MRI to determine soft tissue planes and extent of tumour. This may be particularly relevant where extensive surgical procedures are considered, such as in relatively young patients.

Lastly, where there is the need to determine involvement in the spine, such as seen in tumours that extend into the nerve root foramina, it is important to demonstrate the potential risk to both nerve roots and spinal cord. In such situations, MRI can elucidate the true extent of the tumour and have an impact on both radiation field and/or surgical options.
Detection of lung nodules is challenging given the susceptibility artefact in the lungs. However a nodule >6mm can be demonstrated with reasonable accuracy. Several studies have shown the capability of not just demonstrating the presence of lung nodules, but also the ability of MRI to evaluate the malignant potential of such nodules using a combination of non-contrast and contrast-enhanced techniques, including perfusion imaging. The utility of diffusion weighted imaging has also made its inroads into chest imaging, particularly where the concern is for lung tumours within consolidated lung. In these circumstances, diffusion weighted imaging is capable of making the distinction between the lung tissue and the tumour, as well as give insight into the potential involvement of hilar and mediastinal lymph nodes. Using whole body diffusion weighted imaging is probably accurate enough for staging of lung cancer in comparison to PET.

**Pleural and mediastinal disorders**

As with primary lung cancer, the main reasons for performing MRI in pleural and mediastinal disorders will be to detect soft tissue planes and give better insight into the distribution of tumours. For the pleura, it is quite easy to detect effusions and demonstrate the difference between pleural effusion and soft tissues (something that may be more difficult on standard CT). Pleural lesions, such as metastases, may be better depicted, while the assessment of pleural involvement can also be resolved using dynamic imaging, demonstrating free movement in tumours that are not growing into the chest wall.

Mediastinal disorders, mainly those involving lymph nodes or thymus tumours, can benefit from better delineation of tumours in relation to critical structures, such as the aorta or pulmonary arteries. Nevertheless, most of these lesions will be equally well-depicted using contrast-enhanced CT.

**Pulmonary vascular diseases**

Pulmonary vascular disease is any condition that affects the blood vessels en route between the heart and lungs. Typical conditions seen in radiology include pulmonary hypertension and pulmonary embolism. MRI is a clinically useful tool in the assessment of patients with suspected pulmonary vascular diseases, as it provides a really comprehensive overview of both the structure and function of the heart (figure 2) and the pulmonary vasculature (figure 3). MR perfusion imaging (figure 3) is highly accurate at ruling out chronic thromboembolism, a disease that occurs when pulmonary emboli do not clear the pulmonary arteries, leading to vessel remodelling and narrowing. The jury is still out on the role of MRI in the detection of pulmonary embolism, likely as amount of perfusion defects tends to be, on average, less.

MRI is the gold standard test for assessment of cardiac chambers. In pulmonary hypertension, the right ventricle dilates and hypertrophies in response to the increased resistance in the lungs. These features are exquisitely illustrated and measured with MRI (figure 2) and these changes can be diagnostic, can be used to monitor patients on treatment and can predict mortality. MRI is certainly moving towards the mainstream of PH investigations.

**Cystic fibrosis**

Structural 1H MRI and functional techniques such as Gd-enhanced perfusion imaging and HP gas MRI can reveal early structural and functional changes in CF lung disease. The clinical evidence suggests 1H MRI can now replace chest x-ray for the assessment of structural CP lung disease and is a decent surrogate for chest CT as a means of radiation dose reduction. HP gas MRI has the potential to reveal functional changes in lung ventilation in advance of the structural changes manifested on CT and shows much hope for therapy and longitudinal follow-up in paediatric CF.

**Future developments**

There is growing interest in obtaining MR imaging based methods for the study of various lung diseases. This is based on the fact that structural information can be supplemented by functional information that can further enable the study phenotypes, in addition to the effects of therapeutic interventions. For instance, ventilation defects can be quantified using hyperpolarised noble gas techniques (either 3He or 129Xe), and in combination with proton methods it is feasible to give an accurate measurement of ventilation-perfusion ratios (figures 4 and 5). These techniques are still mainly a research tool, albeit that there are now multicentre studies that have demonstrated the feasibility of uniform protocols, with applications in emphysema, asthma and cystic fibrosis.

The application of T1 mapping is another tool that has generated interest. Thus, it is possible to study T1 maps of interstitial lung diseases, as well as study the effects of perfusion changes in chronic fibrotic and emphysematous lungs. It is highly likely that some of these techniques will ultimately become the standard for new therapeutic trials, as they offer greater insight into functional changes compared to CT measurements.

**Conclusions**

MR of the thorax remains a field under development, and it is worthwhile considering MRI in a variety of niche areas, particularly where additional information about morphologic extent of tumours or functional information about lung diseases are relevant. There are particular populations who may benefit, such as young patients who require life-long follow-up studies (cystic fibrosis, asthma) or where radiation dose is a particularly hazardous issue (including pregnancy).

**Further reading**


24. Van Beek E J, Hill C, Woodhouse N et al. Assessment of lung disease in...
Figure 4
Ventilation MRI study in a normal subject using 129Xe, demonstrating high spatial resolution.

1L natural-abundance Xe (~£20 per scan)

Figure 5
Ventilation MRI using 3He in various lung diseases and pulmonary vascular disease, demonstrating the different patterns that may be observed.