Efficacy of Chest MRI in defining the obstructing lung cancer from adjacent collapse/consolidation

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Authors: K. K. Lau¹, R. McIntyre, C. Daley², S. Stuckey; ¹Victoria/AU, ²AU
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Purpose

Lung cancer is a significant disease in our society because of its high prevalence and the associated morbidity and mortality. It is the leading cause of cancer related deaths, estimated to cause 1.18 million deaths worldwide per year (1,2,3).

A range of imaging modalities can be utilised to characterise lung lesions, stage tumours and to assess for the presence of other associated diseases that may affect management of the patient. Computed tomography (CT) and recently positron emission tomography (PET-CT) have been established as the principal investigative tool in the diagnosis, staging and management of lung cancer. They have the advantages of identifying and characterising the primary lung tumour, and also assessing the metastatic disease and evaluating background lung diseases (4). CT itself provides excellent morphologic information but has significant limitations in differentiating between benign and malignant lesions either in an organ or in lymph nodes (5).

Resectability of the cancer or radiation field size depends on tumour size, which can be difficult to distinguish if there is a distal collapsed or consolidated lung (Figure 1). The associated inflammatory changes leading to loss of the fat plane may result in overestimation of tumor size. It has been shown that PET/CT is a useful tool for the differentiation between tumor, which is hypermetabolic, and peritumoral collapse/consolidation, which is usually normometabolic (6,7).

Like CT scanning, MRI is an anatomic study (8). Strengths of MRI include excellent tissue contrast, multiplanar imaging capability, sensitivity to blood flow, and lack of ionizing radiation. However, application of MRI in intrinsic lung disease has been limited by signal loss from physiologic lung motion, a paucity of protons, and magnetic field inhomogeneities induced by the air/tissue interfaces in lungs (9). It provides a high degree of soft tissue resolution and is superior in its capability to assess lymph node, vascular, chest wall, vertebral and brachial plexus involvement (4,8). MRI can be useful in evaluating superior sulcus tumors, especially with regard to possible invasion of the brachial plexus, and for vertebral invasion (8,10).

The aim of this prospective study was to evaluate the efficacy of MRI in distinguishing the central lung cancer from distal lung collapse/consolidation.
Fig. 1: Post contrast CT of chest in a 54 year old male demonstrated a very poorly defined large right inferior hilar tumour with distal right middle lobe and partial right lower lobe collapse and mild right pleural effusion.

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Methods and Materials

Subjects

Consecutive adult patients of all age and gender who had lobar or segmental lung collapse/consolidation on CT were included in the MRI chest study. The patients had been assessed by the respiratory unit prior to MRI. Patients who could not give consent, were uncooperative or unable to lie flat on the MRI table, were excluded.

MRI

All chest MRI’s were performed on Siemens Symphony TIM 1.5T (Erlangen, Germany). MRI Sequences included axial, coronal and sagittal True FISP, axial and coronal HASTE, axial and coronal T2, DWI (B value of 500 and 900), ADC, axial T1 VIBE, post contrast axial T1 VIBE at 1 min, 3 min and 5 min after Gadolinium injection and coronal T1 VIBE. Respiratory gating was applied. ECG-gated was not required.

PET-CT

Patients would have PET-CT within 3 weeks of MRI’s for correlation. If MRI did not suggest any malignancy, patients might have follow up CT after appropriate clinical assessment by the respiratory unit.

All MRI, PET-CT and follow up CT results were correlated and compared by a blinded radiologist.
Results

14 patients (6 males and 8 females, mean age 60 years with age range of 39 to 82) were included in the study. There was no exclusion.

10/14 patients (71%) were shown to have central tumours on MRI causing distal lung collapse/consolidation. The central tumours had mass like appearance with internal signals different from adjacent collapse/consolidation (Figure 2), and demonstrated diffusion restriction (Figure 3) and early gadolinium enhancement related to increased tumour permeability (Figure 4). The tumour sizes and shapes on MRI and PET-CT were all matched. All these tumours were shown to be malignant on subsequent biopsy under bronchoscopy or CT guidance.

MRI could further evaluate the degree of bronchial compression (Figure 5), tumour extension into Mediastinum (Figure 6) and blood vessels (Figure 7), metastatic involvement of lymph nodes (Figure 8), bone (Figure 9), pleura (Figure 10) and adrenals (Figure 11).

2/14 patients (14.5%) had infective atelectasis (Figure 12) and 2/14 patients (14.5%) had bronchocoele (Figure 13) which showed no diffusion restriction and slow Gadolinium enhancement. 2 of them had PET-CT and the lesions were non-FDG-avid. The lesions of these 4 patients regressed on the follow up CTs.

The pulmonary vein invasion by lung malignancy (Figure 7), malignant deposits within the collapsed lung segment (Figure 14) and malignant pleural effusion (Figure 15) were only detected on MRI, but not diagnosed on PET-CT.

In addition, MRI demonstrates co-existing myocarditis in one patient (Figure 16) and presence of asbestos-related pleural disease in another patient (Figure 17) which were not evident on PET-CT.

From this study, the following observations have been made on the MRI regarding malignant and benign nature of the lung lesions:

1. Morphology

Malignant lung tumours usually have irregular contour with spiculation and may have heterogeneous or necrotic centre (Figure 18) and sometimes with S-sign of 'Golden' while
the benign lesion, eg. segmental collapse, is usually homogeneous and has a smooth contour (Figure 19).

2. **Diffusion restriction**

Lung malignancy tends to contain more restricted water as compared to collapse/consolidation (Figure 3).

3. **Early contrast enhancement and wash-out characteristic**

These were observed in all lung malignancy, except one (Figure 4). This is likely related to neoangiogenesis (a fragile and leaky vascular network with large endothelial gap allowing rapid movement of contrast from the blood stream into the extra-cellular spaces) in the tumour (11). The benign lung lesions, eg. collapse and consolidation, demonstrated slow progressive increase of contrast enhancement over time (Figure 12).

The above characteristics observed in this MRI study helped to differentiate central malignancy from adjacent collapse/consolidation.

However, MRI has disadvantages compared to CT: Being slower and more expensive with poorer spatial resolution and providing limited lung parenchyma information. MRI is also poorly tolerated by claustrophobic patients and is contra-indicated in patients with indwelling electromagnetic devices and some surgical devices (12). These problems may be partly overcome in the future with improvements in imaging hardware and pulse sequences.

**Limitation of this study**

The number of subjects recruited in this study was small, but the MRI findings were promising. A double-blinded randomized controlled study with larger number of patients with bronchoscopic and surgical correlation will confirm the efficacy of MRI in lung cancer characterization and staging.
Fig. 2: Non Gd True FISP MRI (Fig 2a) in a 82 year old male showed a right central tumour (arrow) with mediastinal extension and subtle peripheral consolidation, which was confirmed on the later PET-CT (Fig 2b).

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**Fig. 3:** ADC map of MRI (Fig 2a) in a 37 year old male who had a necrotic tumour in the lingular lobe (arrow) demonstrated diffusion restriction at the periphery of the tumour which was matched by the hypermetabolic FDG-avid tumour tissue on later PET-CT (Figure 2b).

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**Fig. 4:** Post Gd T1 MRI at 1 min (Fig 4a) and 5 min (Fig 4b) in a 82 year old male demonstrated early contrast enhancement of the right hilar malignancy (arrow) with contrast being washout on the delayed MRI. The contrast enhancement of the adjacent collapse (arrowhead) was slowly increasing over time.

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Fig. 5: Non contrast coronal True FISP MRI sequence of a 79 year old male revealed a right inferior hilar mass obstructing the right lower lobe bronchus which was not visualized causing a right lower lobe collapse.

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**Fig. 6:** Non contrast axial True FISP MRI sequence of a 79 year old male demonstrated the mediastinal extension of the right inferior hilar mass lying immediately posterior to the left atrium.

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**Fig. 7:** Post Gd T1 axial MRI sequence of a 54 year old male showed invasion of the right central malignancy into the right superior pulmonary vein (arrow).

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Fig. 8: Post Gd T1 axial MRI sequence of a 65 year old female demonstrated a subcarinal lymphadenopathy (arrow) secondary to the right hilar tumour. This subcarinal lymphadenopathy also compressed onto the adjacent left lower lobe bronchus causing left lower lobe collapse-consolidation.

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Fig. 9: Non contrast coronal True FISP MRI sequence of a 86 year old female with right lung malignancy and adjacent consolidation revealed a thoracic vertebral metastasis (arrow).

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**Fig. 10:** Post Gd T1 axial MRI sequence of a 69 year old female with right hilar malignancy showed diffuse enhancing pleural metastasis (arrow).

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**Fig. 11:** Non contrast coronal True FISP MRI sequence of a 82 year old male showed a right adrenal metastasis (arrow). Right upper lobe consolidation was seen secondary to a central obstructing tumour which was not included on this image.

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Fig. 12: Post Gd T1 MRI sequences at 1 min (Fig 12a) and 5 min (Fig 12b) in a 47 year old female demonstrated a segmental collapse of the left lower lobe with no central mass lesion. The collapse demonstrated steady increase of contrast enhancement over time with no evidence of washout. This would suggest no underlying malignancy and this lesion was shown to have resolved on the follow up CT.

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Fig. 13: Non contrast T2 MRI sequence (Fig 13a) showed a well defined smooth tubular lesion (arrow) in the left lower lobe which did not have any diffusion restriction or significant contrast enhancement. A diagnosis of bronchocoele was made and it showed reduction in size on the follow up CT. PET-CT confirmed non FDG-avid state of the lesion.

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**Fig. 14:** Fat saturated T2 axial MRI sequence of a 54 year old male who had right central tumour (arrow head) causing distal collapse containing tumour deposits (arrow) which demonstrated contrast washout similar to the main tumour. The collapsed segment showed increased contrast enhancement on the delayed contrast sequence.

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Fig. 15: Post Gd T1 axial MRI of a 37 year old male with a left central necrotic malignancy demonstrated a left pleural effusion with pleural thickening and stranding (arrows) raising the suspicion of a malignant pleural effusion. This was confirmed on the subsequent pleural tap.

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**Fig. 16:** Non contrast True FISP axial MRI sequence of a 37 year old male with abnormal signals found in the left ventricular wall (arrows) during the investigation of segmental collapse of lung which was later diagnosed to be myocarditis.

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**Fig. 17:** Non contrast T2 axial sequence of a 87 year old male demonstrated T2 hyperintense lobulated pleural plaques (arrows) secondary to previous asbestos exposure.

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**Fig. 18:** Non contrast True FISP axial sequence of a 37 year old demonstrated an irregular lingular malignancy which had a necrotic centre. It was associated with a mild left pleural effusion.

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Fig. 19: Delayed post contrast T1 axial MRI (Fig 19a) in a 73 year old male showed a well defined smooth enhancing lesion in the right lower lobe with no washout. The lesion showed no diffusion restriction (Fig 19b). PET-CT was negative. This was diagnosed as segmental collapse probably secondary to infection and this resolved on the follow up CT.

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Conclusion

MRI was capable of defining the central tumour from the adjacent lung collapse/consolidation, and therefore, assisting accurate tumour staging. It can be an alternative to PET-CT which may lack the capability of demonstrating tumour invasion into major vessels, tumour deposits in the collapsed/consolidated lungs or malignant pleural effusion as shown in our study.

Possible future implications

1. These lung MRI sequences combining with whole body T2 STIR imaging can be a tool to characterize and stage lung cancer, particularly in the centres where PET-CT may not be readily available.
2. Tumour morphology, diffusion restriction and early dynamic contrast enhancement with wash-out as observed in this study may help to predict the nature of observed lung lesions, i.e. malignancy vs benignity.
3. The MRI chest may also reveal underlying cardiac/major coronary abnormalities, which are commonly found in lung cancer patients with a smoking history and may alter the management plan.
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