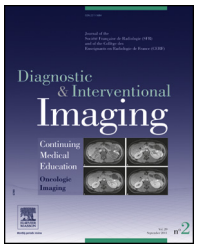
Diagnostic and Interventional Imaging (2016) xxx, xxx—xxx



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Contribution of magnetic resonance imaging in lung cancer imaging

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KEYWORDS
Thorax;
Lung cancer;
Magnetic resonance imaging;
TNM staging;
Diffusion-weighted images

Abstract Lung cancer is the leading cause of cancer death worldwide. Prognosis and treatment outcomes are known to be related to the disease stage at the time of diagnosis. Therefore, an accurate assessment of the extent of disease is critical to determine the most appropriate therapy. Currently available imaging modalities for diagnosis and follow-up consist of morphological and functional imaging. Morphological investigations are mainly performed with CT-scan and in some cases with MRI. In this review, we describe the contribution of MRI in lung cancer staging focusing on solid pulmonary nodule characterization and TNM staging assessment using chest and whole-body MRI examinations, detailing in each chapter current recommendations and future developments.

Lung cancer is the leading cause of cancer death worldwide. Prognosis and treatment outcomes are known to be related to the disease stage at the time of diagnosis [1]. Therefore, an accurate assessment of the extent of disease is critical to determine the most appropriate therapy. Currently available imaging modalities for diagnosis and follow-up consist of morphological and functional imaging. Morphological investigations are mainly performed with computed tomography (CT) and in some cases with magnetic resonance imaging (MRI). Given its adequate spatial resolution and wide availability of this imaging modality, chest CT-scan is the primary and most commonly used modality for early diagnosis and initial staging of patients with lung cancer based on morphologic criteria. Recent CT developments involve perfusion and spectral imaging with promising results on tissue characterization.

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http://dx.doi.org/10.1016/j.diii.2016.08.015
2211-5684/

Functional investigations are dominated by 18-fluorodeoxyglucose positron emission tomography CT (^{18}FDG PET-CT) using ^{18}FDG uptake and by the recently emergent whole-body MRI including morphological and functional sequences such as diffusion-weighted imaging (DWI). ^{18}FDG-PET-CT has demonstrated efficacy in the initial staging of lung cancer with a variable avidity and limited spatial resolution in the detection of adenocarcinomas, with a considerable number of false-positive findings due to inflammatory changes and chronic disease [2]. Other limitations of ^{18}FDG-PET/CT are brain staging and the fact that it is associated with a considerable radiation burden to patients and medical personnel. The radiation dose for a chest CT-scan varies between 1—10 mSv while that of whole body ^{18}FDG-PET/CT is 10—30 mSv.

MRI is currently the only technique that enables non-invasive whole-body assessment without ionizing radiation. Moreover, in case of significant renal impairment if other modalities are considered inadequate and there is a clinical benefit of a contrast enhanced imaging procedure, we prefer the use of enhanced MRI than enhanced CT [3].

MRI has superior soft tissue contrast with high spatial resolution but it is more susceptible to cardiac and respiratory motion artifacts, affected by low proton density, very short T2* values, and inhomogeneity of the magnetic field in the lungs. However, recent advances in MRI techniques and the use of gadolinium chelates have improved the diagnostic capabilities of MRI in detecting and staging lung cancer. MRI provides not only morphologic but also functional information with diffusion-weighted and perfusion sequences. DWI has been put forward in the past few years as a new technique for evaluating nodal involvement. This technique can provide qualitative and quantitative information about the integrity of cell membrane and tissue consistency, which reflects changes at a cellular level [4].

In this review, we describe the contribution of MRI in lung cancer staging focusing on solid pulmonary nodule characterization and TNM staging assessment using chest and Whole-body MRI examinations, detailing in each chapter current recommendations and future developments.

MRI technique

We are distinguishing two types of sequences: morphological and functional. Artifacts generated by breathing and cardiac motions can be solved with consecutive breath-hold technique and with the use of respiratory cycle and/or cardiac gated imaging.

Morphological sequences

Due to respiratory artifacts we prefer the use of breath-hold sequences, which is possible with the use of parallel imaging methods and/or slice interpolation techniques. These sequences enable full lung volume coverage with slice thickness of 3 to 5 mm acquired during consecutive breath holds (e.g. VIBE ''Volume Interpolated Breath-hold Examination'' for Siemens; LAVA ''Liver Acquisition with Volume Acceleration'' for GEMS etc.). It can be performed on 2D or 3D, with or without fat suppression or with a DIXON technique (Water, Fat, In-Phase, Out-Phase) for anatomical and tissue characterization. Non-contrast enhanced images are preferably acquired without fat suppression or with Dixon technique to facilitate the detection of lymph nodes within the mediastinal fat or the extension within the chest wall. Enhanced images are preferably acquired with fat suppression, increasing the signal difference with the fat around the lesion and showing more precisely the heterogeneity of the enhancement.

Other T1 sequences to be used are the Fast Spin-Echo T1-weighted imaging (FSE T1-WI), the same sequence used for the spine or spinal cord exploration. The spatial resolution has to be increased by reducing slice thickness (2 to 3 mm) and the field of view (240 mm). To preserve the signal to noise ratio, the number of excitations (3 to 5) has to be increased. These sequences are very helpful to identify the tumor extension through the chest-wall especially in the superior sulcus tumor.

Breath-hold short tau inversion recovery (STIR) and free-breathing STIR are used in transverse or coronal plane in the whole body exploration. For sulcus tumor exploration this sequence has to be used in free breathing, in the sagittal plane with 4 to 5 mm slice thickness.

Rotating phase encoding T2-WI (T2 Propeller ''Periodically Rotated Overlapping ParallEL Lines with Enhanced Reconstruction'' for GEMS; BLADE for Siemens) produces images with correction of respiratory and cardiac motion artifacts. This sequence can be used in breath-hold or respiratory triggering with or without fat suppression.

Functional sequences

In lung cancer imaging functional MRI has a dual role: exploration of the macroscopic motion (cardiac and respiratory movements) and microscopic random motion (diffusion imaging). Tumor perfusion with MRI for lung cancer is not yet fully developed for clinical use.

Images obtained during the cardiac cycle (same MRI sequence used to evaluate the cardiac function) allow dynamic visualization of structure mobility (cardiac chambers or great vessels of the mediastinum) in contact with the tumor. These sequences are cardiac- gated usually with breath-hold technique. Slice position has to be perpendicular to the interface between the tumor and the vascular structure.

To identify structure mobility in contact with the chest wall, as a very sensitive sign of chest wall involvement by the tumor, we have to obtain dynamic images during multiple consecutive respiratory cycle with deep inspiration followed by deep expiration, called as Rrespiratory Dynamic MRI. Using sequences of high temporal resolution (acquisition time for one slice < 0.5 second), allows us to obtain a sufficient number of images during one respiratory cycle. Images obtained during a multiple respiratory cycle permit the visualization of the tumor shift in contact with the chest wall in order to rule out the chest wall invasion by the tumor. Adequate sequences for this exploration are for instance FIESTA (Fast Imaging Employing Steady sTate Acquisition) for GEMS and HASTE (Half-Fourier Acquired Single-shot Turbo spin Echo) for Siemens.

Please cite this article in press as: Khalil A, et al. Contribution of magnetic resonance imaging in lung cancer imaging. Diagnostic and Interventional Imaging (2016), http://dx.doi.org/10.1016/j.diii.2016.08.015