Global *Journal of Imaging and Interventional Medicine*
2021; 2(1):12-18.
ISSN Online: 0000-0000; ISSN Print: 0000-0000
Website: http://naturescholars.com
Email: Glo_J_Iim@126.com
Publisher: Scholars Publishing, LLC

Review

Research Progress of MRI-Assisting Low Dose CT in Evaluating The Benign and Malignant Value of Pulmonary Nodules

Jingya Zheng[1], Yuanyi Huang[2,✉]

[1]Department of Imaging and Nuclear Medicine, The Second Clinical Medical College of Yangtze University, Jingzhou, Hubei 434020, China; [2]The Second Clinical Medical College of Yangtze University, Jingzhou, Hubei 434020, China.

✉Correspondence
Yuanyi Huang, Radiology Department, The Second Clinical Medical College of Yangtze University, Jingzhou, Hubei 434020, China. Email: yyhuangjz@163.com. Telephone number: 18107167061.
Received: November 7, 2020. Accepted: December 30, 2020. Published online: January 7, 2021.
Cite this paper: Jingya Zheng, Yuanyi Huang (2021). Research progress of MRI-assisting low dose CT in evaluating the benign and malignant value of pulmonary nodules. *Global Journal of Imaging and Interventional Medicine*, 2(1):12-18. http://naturescholars.com/gjiim.020102. https://doi.org/10.46633/gjiim.020102.

Abstract

Lung cancer is the leading cause of cancer death worldwide. Only an accurate assessment of the stage of lung cancer can determine the most appropriate treatment. Due to the physiological activities of lung and mediastinum, MRI has not been routinely used in clinical staging, diagnosis and treatment of lung cancer (1,2). With the emergence of ultra-low dose CT (ULDCT) and low-dose CT (LDCT), the radiation dose of CT used for screening pulmonary nodules is gradually reduced (3). However, benign and malignant pulmonary lesions sometimes have similar characteristics on CT. Pet-CT is often needed for diagnosis or puncture biopsy (4,5). Therefore, thoracic MRI assisted LDCT to evaluate the benign and malignant pulmonary nodules was born (3). In this review, we will explore the use of thoracic MR imaging to assist LDCT in the assessment of benign and malignant pulmonary lesions and the stage of lung cancer.

Key words: Lung Cancer, Cancer Screening, Magnetic Resonance Imaging, Pulmonary Nodules, Low Dose CT.

Introduction

Lung cancer is a serious threat to human health. Many early lung cancer detection activities worldwide are driven by the fact that early detection and treatment can greatly improve the prognosis of the disease. LDCT is commonly used for pulmonary examination, while magnetic resonance imaging (MRI) is rarely used due to the limitation of pulmonary respiratory movement and heartbeat. With the development of (MRI) hardware and software, the limitations of lung MRI examination

have been broken (6). Lung MR imaging is increasingly used in primary lung cancer screening or as an auxiliary CT scan. In this review, we focus on the advantages of MRI as an auxiliary scan for CT examination and the current application scope and future prospect of chest MRI examination are summarized.

1. Research status of MRI

In current stage, MRI examination still has limitations. A chest MRI examination takes about 20 minutes, whereas an LDCT examination generally takes only 5 minutes. In addition, the patients suffer from a lot of noise during MR examination and 5-30% of patients often feel very painful during MR examination as their whole body needs to enter the coil with a narrow space (7). MRI can achieve radiation-free lung imaging, but the image quality is easily affected by respiratory and cardiovascular motion artifacts. However, with the continuous improvement of magnetic field intensity, continuous optimization of rapid imaging sequence and continuous shortening of scanning time, the influence of motion artifacts can be minimized to improve the signal-to-noise ratio and spatial resolution of lung images.

The clinical application of lung MR imaging is growing. Standardized scanning protocols (transverse T1WI, T2WI, DWI and coronal T2WI) have been established gradually. Because of the high air content, the proton density in the lungs is low. therefore the MR signal of lungs is low as it is proportional to the proton density. Although increasing magnetic field strength can theoretically enhance image signal-to-noise ratio, in fact, the existence of air tissue exchange interface will make MR inspection vulnerable to the influence of magnetic field heterogeneity, leading to the increase of susceptibility artifacts (8). Therefore, some studies on the advantages of low-field intensity MR in the diagnosis of lung cancer are being carried out (9). LDCT provides limited information about pulmonary nodules and often requires puncture for confirmation. MR examination can be performed by morphological imaging at different levels (transverse dislocation, coronal dislocation and oblique dislocation), sequence and parameters (T1/T2/ proton density), as well as functional imaging through DWI (6). It can be combined with CT examination to evaluate the benign and malignant tumor. Reduce the incidence of surgical complications in patients. Early clinical studies also found that the false positive rate of MR detection of lung cancer was much lower than that of LDCT (10). In addition, Some scholars indicated that when CT plain scan morphological examination could not assess the benign and malignant pulmonary nodules in patients with severe kidney injury and was not suitable for CT enhanced examination. Routine MR plain scan plus DWI could be used for auxiliary assessment. In addition, MR enhancement requires much less contrast agent than CT enhancement. Alternatively, MR enhancement can be chosen to reduce the damage to the kidney (2).

2. Research progress on MRI technology

The transverse location is the most intuitive level to observe the lung tissue. And sometimes the relationship between tumor and blood vessels can be more clearly observed in the disordered location and coronal location (11). To reduce the artifact of respiration and heartbeat movement, patients should be trained before MRI and use Cardio-electric control and respiratory gating during the examination. MRI can be divided into morphological sequence and functional sequence.

2.1 Research progress of morphological sequence

Since the lungs are respiratory organ, to prevent the generation of movement, artifacts T1 breath-hold sequence should be used to complete the scanning of the entire lung field (such as Siemens 3D VIBE sequence and GE LAVA sequence). However, the use of the breath-hold sequence may limit the acquisition time and cause

the image spatial resolution to decrease. In addition, many patients with pulmonary nodules may be associated with chronic obstructive pulmonary disease or older. so it is often difficult to hold air (8). Therefore, T1 can choose star VIBE sequence triggered by free breathing, which has a high image spatial resolution and a good display effect on the size and shape of pulmonary nodules and mediastinal lesions. In addition, T1 can also adopt fast spin echo sequence (Siemens named TSE sequence/GE named FSE sequence), which is highly sensitive to the difference between air and lung tissue (12). However, the layer thickness must be controlled within 2-3mm and the scanning field within 240mm to ensure the spatial resolution of the image. Meanwhile, the excitation times should be increased to 3-5 times to ensure the signal-to-noise ratio of the image. This sequence showed a good effect on tumors extending to the chest wall and the detection rate of malignant nodules was comparable to LDCT. T2 Blade free breathing trigger sequence can be selected. And its image spatial resolution is relatively high. T2 Blade can also be selected for breath holding mode scanning. The scanning time is short. But the image resolution and signal-to-noise ratio are poor. In addition, new MR imaging techniques, such as radial K-space sampling, ultra-short echo time imaging (UTE), and fast three-dimensional balanced steady state free processional sequence (bSSFP) have advantages in displaying tumor adjacent structures: pleura, ribs, mediastinum, nerve roots. These information can provide important evidence for tumor staging (13). This makes it possible for MR to be used as an auxiliary LDCT for the detection of pulmonary nodules. However, T2-weighted imaging is still the key sequence for lesion observation (14).

2.2 Research progress of functional sequence

2.2.1 Diffusion-weighted magnetic resonance imaging (DWI)

A number of studies have proved that: DWI can visually show lung cancer and metastatic lymph nodes and distinguish lung cancer from obstructive pulmonary collapse (15,16). In addition, systemic DWI imaging can be used to evaluate the presence or absence of distant metastasis and M staging in lung cancer patients (17). Pet-CT is less sensitive to bone metastasis of lung cancer than systemic DWI. Katsuo et al. showed that the sensitivity of lung cancer recurrence and metastasis was 100% on DWI, 82% on CT and 89% on PET-CT. There were statistically significant differences in the sensitivity of lung cancer recurrence and metastasis detected by DWI and CT (P=0.024), but no statistically significant differences between DWI and PET-CT (P=0.22) (18). Therefore, DWI can be used for radiation-free diagnosis of lung cancer metastasis and recurrence, especially hilar/mediastinal lymph node, bone and liver metastasis, and the examination cost is much cheaper than PET-CT (Figure 1). Meanwhile, DWI has been proved to be superior to CT and PET-CT in showing the contour of atelectasis lung tumors (19). However, due to the difference in sensitivity of air tissue interface, the obtained images may be distorted. New technologies are expected to solve this problem in the future (1).

2.2.2 Apparent dispersion coefficient (ADC)

ADC is a parameter that can distinguish benign from malignant soft tissue. Shen et al reported that the ADC value of malignant tumors (1.21 mm^2/s) was significantly lower than that of benign lesions (1.76 mm^2/s) (20). However, there is still no consensus on the optimal cut-off ADC value between benign and malignant lung tumors (2). In addition, abscesses, necrosis, and thrombus can inhibit the diffusion of water molecules, thus affecting the focal ADC value. the study of Jiang Yang et al. showed that we can add a large local volume uniform field and reduce phase coding to increase magnetic field uniformity and reduce magnetic sensitivity artifacts, so as to improve image quality without affecting the ADC value of

the image (21).

2.2.3 Chemical exchange saturation transfer (CEST) MR

CEST MR is a novel medical imaging technology which can provide molecular level information of tissue microenvironment. Amide proton transfer (APT) is an imaging method of CEST MR. Previous studies have shown that APT contrast in tumor tissues is higher than that in normal tissues. Histopathology confirmed that APT signal strength was related to tumor grade. Therefore, in the future, measuring APT concentration in tumor tissues will become a non-invasive and radiation-free method to evaluate tumor grade. It is even expected to guide the clinical treatment of tumors (22,23).

3. Research progress of MRI quality

Recent developments in MR techniques have improved the sensitivity for 5 mm nodules to 100%. For nodules larger than 5 mm in diameter, LDCT combined with MR is recommended to evaluate the benign and malignant pulmonary nodules. For nodules with the diameter less than 5 mm, as the sensitivity and specificity of MR are much lower than LDCT, LDCT is only recommended. Some scholars found that both sensitivity and specificity of MR detection for solid and subsolid nodules with diameter ≥6mm were very high . It could be used to evaluate the benign and malignant lung tumors (14,24). The malignant lung tumor presented isosignal on T1, high signal on T2, limited diffusion on DWI and ADC value is less than 1.21 mm^2/s (20) (Figure 2/3/4).

4. Comparison of MRI scan and CT scan

Due to the characteristics of multi-plane imaging and high soft tissue resolution, when the tumor extends to the chest wall, intervertebral foramen and vertebral canal or involves the brachial plexus, MR display effect is significantly better than CT (25-27). When peripheral pulmonary nodules are near the chest wall, It does not necessarily mean that the tumor invades the chest wall. Tumor invasion of the chest wall is assessed by adjacent rib breakage, pleural invasion, and loss of fat interface in the chest wall. Since MR is sensitive to fat signals, T1 shows a high signal. The lung and bone cortex show low signal due to low proton density. Therefore, the fat interface of chest wall can be clearly displayed on MR (11,16). At the early stage of pleural invasion, the benign and malignant stage of the tumor was evaluated by the loss of the fat interface in the chest wall. However, LDCT is inferior to MRI in distinguishing tumor adjacent to pleura or invasion due to low soft tissue resolution (6). In addition, T2-weighted imaging makes the pleural wall easier to observe because of the high signal. STIR sequence clearly shows the extent of rib damage.

When solid pulmonary nodules are located between multiple pulmonary arteries, it is easy to miss diagnosis on LDCT or not suitable to distinguish the relationship between solid nodules and adjacent vessels because CT values of solid nodules and pulmonary vessels are similar. Due to the high resolution of soft tissue and the blood's cavitation effect, additional MR examination makes the blood vessels show low signal and tumor tissues show medium signal, which makes it easier to find nodules and observe the relationship between nodules and adjacent blood vessels from the perspective of loss/crown/axial multi-orientation, as well as whether the tumor invades blood vessels (11,14). At the same time, equal-signal or high-signal lung lesions are easy to detect due to the low signal black background of normal lung tissue on MR.

When LDCT scan of pneumoconiosis patients does not show typical CT manifestations of pulmonary fibrosis and clinical symptoms are not typical, puncture is often required to distinguish pulmonary fibrosis and lung cancer. Currently, auxiliary chest MR non-invasive examination is

helpful to diagnose the disease and avoid the occurrence of puncture complications. T2 plain scan of pulmonary fibrosis lesions showed low signal. Lung cancer showed equal or high signal. T2 enhanced pulmonary fibrosis showed uniform enhancement, while lung cancer showed uneven or circular enhancement (28). In addition to pneumoconiosis, infiltrating lung is also suitable for MR examination. Juergen et al. found that T1 and proton dense-weighted imaging were highly sensitive to intrapulmonary effusion (10). In addition, LDCT has limited ability to differentiate between inflammation and fibrosis, edema, and tumor in the lung. MRI has obvious advantages in distinguishing these tissues due to the high resolution of soft tissue.

Sommer et al. found that the false-positive rate of MR for lung cancer screening was only 5%, while the false-positive rate of LDCT for lung cancer screening was as high as 23.3% in NLST test (10). Published studies strongly suggest that pulmonary MRI may be a potentially effective tool for lung cancer screening because it is similar in sensitivity to CT in the detection of pulmonary nodules and has a lower false positive rate. MRI can be used as an additional test for LDCT positive patients, although the efficiency of MRI in lung cancer screening is low under current hardware and software equipment conditions. It plays a role in characteristic-assessment. We expect that in the future, with the continuous improvement of MR spatial resolution and the continuous acceleration of scanning speed, CT examination will be replaced by MR imaging due to radiation exposure in lung cancer screening.

Of course, LDCT also has its own unique advantages: due to its high spatial resolution, it is significantly better than MR in showing tumor margins (such as burr, lobulation, and pleural linear traction) and tumor interior (such as cavitation, necrosis, calcification, vacuolation), and these morphological features are also important basis for benign and malignant evaluation of tumors. Interlobular fissures, which are used to define tubercular lobules, are also often obscured on MR (11).

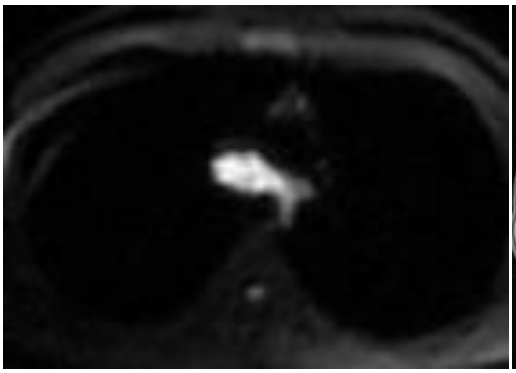

Figure 1. DWI image of lymph nodes

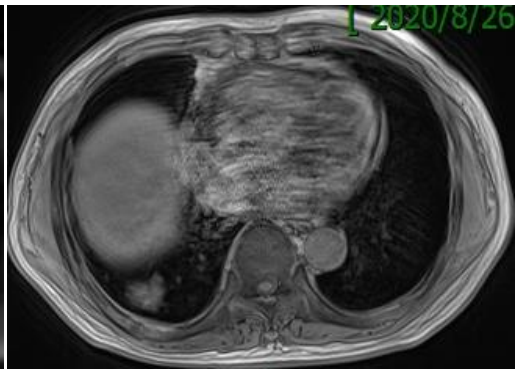

Figure 2. T1 image of adenocarcinoma

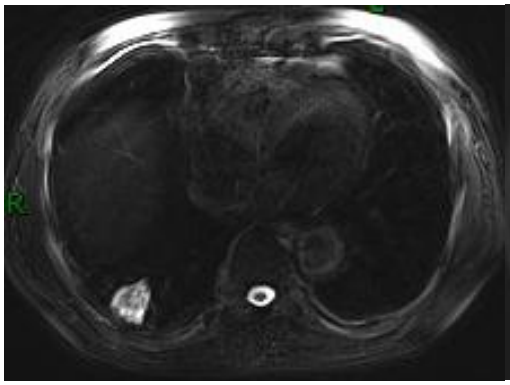

Figure 3. T2 image of adenocarcinoma.

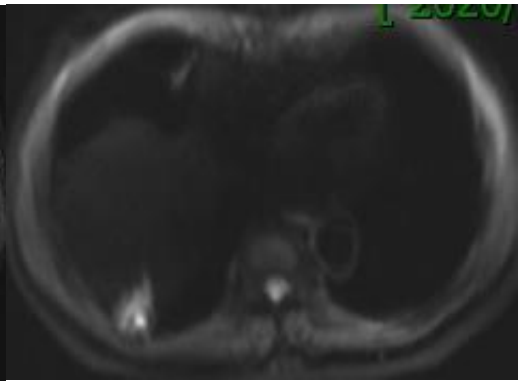

Figure 4: DWI image of adenocarcinoma.

Conclusion

The use of MR in the lungs has lagged the brain, uterus, prostate and other resting organs. With the increasing application of new MR sequences and functional imaging in pulmonary diagnosis, monitoring and staging, it was found that, compared with thin-slice spiral CT, the main limitation of MR is the poor display effect on nodules below 6 mm (1). However, it is superior in determining the relationship between tumor and adjacent tissues and the degree of invasion. It was expected that, in the future, MR could be used independently to screen for lung cancer, to guide lung cancer treatment or to review any diameter of pulmonary nodules.

Declarations

1) **Consent to publication**
   We declare that all authors agreed to publish the manuscript at this journal based on the signed Copyright Transfer Agreement, and followed publication ethics.
2) ***Ethical approval and consent to participants***
   Not applicable.
3) ***Disclosure of conflict of interests***
   We declare that no conflict of interest exists.
4) ***Funding***
   None
5) ***Availability of data and material***
   We declare that the data supporting the results reported in the article are available in the published article.
6) ***Authors' Contributions***
   Authors contributed to this paper with the design (HYY), literature search (ZJY), drafting (ZJY), revision (HYY and ZJY), editing (ZJY)and final approval (HYY).
7) ***Acknowledgement***
   None
8) ***Authors' biography***
   None

References

1. Austin J. S,Evangelia K,Lisa S,et al. A review of the role of MRI in diagnosis and treatment of early stage lung cancer[J]. Clinical and Translational Radiation Oncology,2020,24:16-22.
2. A. Khalil,M. Majlath,V. Gounant, et al. Contribution of magnetic resonance imaging in lung cancer imaging[J]. Diagnostic and Interventional Imaging,2016,97(10) :991-1002.
3. Ioannis V, Konstantinos S, Sarah S,et al.Lung cancer screening: nodule identification and characterization[J]. Translational Lung Cancer Research, 2018,7(3):288-303.
4. Lei Y,Li X,Wang Q, et al. Incoherent motion diffusion-weighted imaging in Mr Voxels of peripheral lung cancer [J]. Chinese medical imaging technology, 2015,31 (01):57-61.
5. Xiao W,Lei R,Zhou Q,et al. Application analysis of CT-guided percutaneous lung biopsy in lung space-occupying diseases (Report of 42 cases) [J]. Journal of Yangtze University (Self science edition) Medical Volume,2008,5(04):24-25+5.
6. Li M,Qiao P,Li G, et al. MRI diagnosis of primary lung cancer [J]. Journal of Medical Imaging，2017,27（3）:465-8.
7. Ruth E,Stuart T,Sam J,et al. Patient experience and perceived acceptability of whole-body magnetic resonance imaging for staging colorectal and lung cancer compared with current staging scans: a qualitative study[J]. BMJ Open,2017,7(9).
8. Wild JM, Marshall H, Bock M, et al. MRI of the lung (1/3): methods. Insights Imaging. 2012,3(4):345-53.
9. Muller CJ, Loffler R, Deimling M, et al. MR lung imaging at 0.2 T with T1-weighted true FISP: native and oxygen-enhanced.[J]. Journal of magnetic resonance imaging : JMRI,2001,14(2):164-8.
10. Juergen B,Yoshiharu O,Hiroto H, et al. Screening for lung cancer: Does MRI have a role?[J]. European Journal of Radiology,2017,86:353-60.
11. Chi H,Lu D,Zhao S. Magnetic resonance imaging diagnostic analysis of lung cancer [J]. World's latest Medical Information Digest,2015,15(99):156-7.
12. Hisanobu K,Yoshiharu O,Atsushi K,et al.

Quantitative and qualitative assessment of non-contrast-enhanced pulmonary MR imaging for management of pulmonary nodules in 161 subjects[J]. European Radiology,2008,18(10):2403-4.

13. Raptis CA,McWilliams SR,Ratkowski KL,et al. Mediastinal and Pleural MR Imaging: Practical Approach for Daily Practice.[J]. Radiographics : a review publication of the Radiological Society of North America, Inc,2018,38(1):37-55.
14. Michael M,Rami H,Dirk S,et al. Lung cancer screening with MRI: results of the first screening round[J]. Journal of Cancer Research and Clinical Oncology,2018,144(1):117-125.
15. Hochhegger B,Marchiori E,Sedlaczek O,et al. MRI in lung cancer: a pictorial essay.[J]. The British journal of radiology,2011,84(1003):661-8.
16. Li P,Xiao P,Lei T,et al. Using diffusion-weighted MR imaging for tumor detection in the collapsed lung: a preliminary study[J]. European Radiology,2009,19(2):333-41.
17. Ohno Y,Koyama H,Onishi Y,et al. Non-small cell lung cancer: whole-body MR examination for M-stage assessment--utility for whole-body diffusion-weighted imaging compared with integrated FDG PET/CT.[J]. Radiology,2008,248 (2):643 -54.
18. Usuda K,Sagawa M,Motomo N,et al. Recurrence and metastasis of lung cancer demonstrate decreased diffusion on diffusion-weighted magnetic resonance imaging.[J]. Asian Pacific journal of cancer prevention : APJCP, 2014, 15 (16):6843-8.
19. Zhang X,Fu Z,Gong G,at al. Implementation of diffusion-weighted magnetic resonance imaging in target delineation of central lung cancer accompanied with atelectasis in precision radiotherapy.[J]. Oncology letters,2017,14 (3):2677 -82.
20. Shen G, Jia Z, Deng H. Apparent diffusion coefficient values of diffusion-weighted imaging for distinguishing focal pulmonary lesions and characterizing the subtype of lung cancer: a meta analysis. Eur Radiol 2016;26:556-66.
21. Jiang Y,Pan J,Ying M, at al. Optimization of magnetic resonance diffusion- weighted imaging technique for pulmonary nodules [J]. Journal of Chinese Medical Computer Imaging,2014,20(04):385-8.
22. Jones K,Stuehm C,Hsu C,et al. Imaging Lung Cancer by Using Chemical Exchange Saturation Transfer MRI With Retrospective Respiration Gating.[J]. Tomography : a journal for imaging research,2017,3(4):201-10.
23. Togao O,Yoshiura T,Keupp J,et al. Amide proton transfer imaging of adult diffuse gliomas: correlation with histopathological grades. [J]. Neuro- oncology,2014,16(3)：441-8.
24. H.Koyama,Y.Ohno,A.Kono,et al. Quantitative and qualitative evaluation of 161 patients with pulmonary nodules by NON-enhanced MRI [J]. Journal of International Medical Radiology, 2008,31(6):520.
25. Kishor K,Siddharth S,Geoffrey D. H,et al. Variabilities of Magnetic Resonance Imaging–, Computed Tomography–, and Positron Emission Tomography–Computed Tomography–Based Tumor and Lymph Node Delineations for Lung Cancer Radiation Therapy Planning[J]. International Journal of Radiation Oncology, Biology, Physics,2017,99(1):80-9.
26. Kazuhiro I,Yoshihiro M,Hajime S,et al. Diagnostic imaging in the preoperative management of lung cancer[J]. Surgery Today,2014,44(7):1197-206.
27. Jochen F,Michael J,Stephanie K,et al. The Impact of Diffusion-Weighted MRI on the Definition of Gross Tumor Volume in Radiotherapy of Non-Small-Cell Lung Cancer[J]. PLOS ONE,2016,11(9):1- 11.
28. Ogihara Y,Ashizawa K,Hayashi H,et al. Progressive massive fibrosis in patients with pneumoconiosis: utility of MRI in differentiating from lung cancer.[J]. Acta radiologica (Stockholm, Sweden : 1987),2018,59(1):72-80.