

# Evaluation of pulmonary nodules by magnetic resonance imaging sequences: which sequence will replace computed tomography?

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## SUMMARY

**OBJECTIVE:** This study aimed to determine the role of magnetic resonance imaging in minimizing radiation exposure, especially in the follow-up of pulmonary nodules.

**METHODS:** Patients who applied to our hospital between April 2013 and August 2018 for various reasons and had lung-mediastinal dynamic magnetic resonance imaging and thoracic computed tomography were included in the study. A total of 194 patients were included in the study, involving 84 females and 110 males. Scanning of the nodules was done retrospectively. This study was conducted by two readers: a thoracic radiologist with 15 years of experience and a nonspecific radiologist with 4 years of experience. Evaluations were made using the double-blind method.

**RESULTS:** Of the 194 patients, 84 (43.3%) were female and 110 (56.7%) were male. For the first reader, 135 (69.5%) nodules were detected in postcontrast T1 vibe images, 130 (67%) in T2 fast spin echo, 128 (66%) in precontrast T1 vibe, and 98 (50.5%) in T2 turbo inversion recovery magnitude sequence. For the second reader, 133 (68%) nodules were detected in postcontrast T1 vibe images, 120 (61.9%) in T2 fast spin echo, 122 (62.9%) in precontrast T1 vibe, and 99 (51%) in T2 turbo inversion recovery magnitude sequence. Capability levels were examined in detecting nodules between the first and second readers, and the ratios were reached at 0.92 in T2 fast spin echo, 0.81 in postcontrast T1 vibe images, 0.93 in precontrast T1 vibe, and 0.96 in T2 turbo inversion recovery magnitude sequence.

**CONCLUSION:** In this study of detecting pulmonary nodules by magnetic resonance imaging, which we performed with two different readers, one of whom was an experienced thoracic radiologist, both readers found the highest detection rate in the postcontrast T1 vibe sequence.

**KEYWORDS:** Magnetic resonance imaging. Radiation exposure. Lung.

## INTRODUCTION

A pulmonary nodule is less than 3 cm in diameter and is surrounded by lung parenchyma. They are focal single lesions with oval or round walls which are not accompanied by pathologies such as atelectasis, lymphadenopathy, or pneumonia<sup>1,2</sup>. Larger diameter nodular lesions, also called masses, do not fall into this definition, because most of the nodules larger than 3 cm are malignant<sup>3,4</sup>.

There are many pathologies that can cause pulmonary nodules, the most common being granulomas, lung cancer, and hamartomas<sup>5,6</sup>. The radiological properties of nodules are as follows: its size, whether it contains calcification, in which part of the nodule calcification is located; the contour characteristics; the presence of satellite lesions; and, most importantly, whether the size and nature change are detected in the follow-up images. These features have made computed tomography (CT) the gold standard imaging method in detection and follow-up of

lung nodules. Although ionizing radiation dose exposure has been reduced with the developing technology, it could not be reset. The detection, scanning, and follow-up of these nodules are performed by CT. These procedures cause cumulative radiation exposure to the patient and, in some cases, even the development of radiation-related malignancies. The use of magnetic resonance imaging (MRI) in the thorax is to primarily detect mediastinal and thoracic wall invasions of masses. Indications for the use of MRI in the thorax are increasing<sup>5,6</sup>.

In this study, we aimed to determine the location of MRI, which is an imaging method that does not contain ionizing radiation, in order to reduce the exposure dose in the detection and follow-up of nodules. In this context, a retrospective study was conducted to determine the sensitivity of MRI in detecting nodules. In addition, our study aimed to show the detectability rather than the size difference between MRI and CT.

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## METHODS

Ethical approval was obtained by the Ethics Committee of the Atatürk Faculty of Medicine Clinical Research with decision number 16, dated September 28, 2017.

### Patient selection and evaluation

Patients who applied to our hospital between April 2013 and August 2018 for nodules examination or other reasons (e.g., invasion of the masses in the mediastinum and thoracic wall, mediastinal masses, metastasis, and rheumatoid nodules) and had lung-mediastinal dynamic MRI and thoracic CT were included in the study. In the evaluation of these patients, oval or round lesions smaller than 3 cm in diameter were considered. A total of 194 patients (84 females and 110 males) were included, with the mean age of 18 years. Patients with an examination time of 3 months or less between CT and MRI were included in the study. Scanning of the nodules was done retrospectively. Consent was not obtained from the patients participating in the clinical trial due to the review being done retrospectively. This study was conducted by two readers: a thoracic radiologist with 15 years of experience and a nonspecific radiologist with 4 years of experience. The readers evaluated the nodules by analyzing the MRI sequences, but not the CT images. Then, 1 month after the evaluation of MR images, both radiologists viewed the CT images.

### Magnetic resonance imaging and computed tomography techniques

The evaluation of the patients was performed with 256-slice dual-energy CT (Somatom Flash, Siemens) and 3 Tesla (Skyra, Siemens) devices. CT images were obtained as nonenhanced HRCT (high-resolution computed tomography). All patients underwent HRCT and a 1-mm-thick section was taken for HRCT. Images for HRCT were taken with a bone algorithm. MR images with gadolinium with intravenous contrast, precontrast T1 volumetric interpolated breath-hold examination (vibe), three-dimensional (3D) gradient-echo (GRE), T2-weighted half-Fourier acquisition single-shot turbo spin-echo (HASTE), fast spin echo (FSE), T2 turbo inversion recovery magnitude (TIRM), and parenchymal phase contrast dynamic T1 vibe taken at 90 s were used as imaging sequences. For MRI, 0.5 and 1 mmol/mL solution preparations containing gadolinium were used as contrast. The MRI parameters are as follows: T1 vibe: TR/TE 3,1/1,1; slice thickness, 5 mm; slice gap value, 1 mm; matrix value, 256×256; and field of view (FOV), 350–400 mm for axial images. T2 HASTE: TR/TE 1,400/100; slice thickness, 5 mm; slice gap value, 1 mm; matrix value, 256×256; and FOV, 350–400 mm for axial images. T2 TIRM: TR/TE

3030/107; inversion time, 160 ms; slice thickness, 5 mm; slice gap value, 1 mm; matrix value, 256×256; and FOV, 350–400 mm for axial images.

### Image evaluation

Solid density nodules were included in our study for CT. In addition, the nodules were evaluated according to their lung lobes, detection rates in size ranges, and contrast material factor for MRI. In measuring the nodule size, mean measurements of the longest and shortest diameter parallel to the long axis of the thorax were taken in the parenchyma window in axial sections on CT. On the MR images, precontrast T1 vibe, contrast-enhanced T1 vibe in the parenchyma phase, T2-weighted, T2 TIRM, and detectable nodules were also measured parallel to the long axis of the thorax.

### Statistical analysis

The SPSS 23.0 package program was used for the statistical analysis of the data. Categorical measurements were summarized as numbers and percentages, and continuous measurements as mean, deviation, and minimum-maximum. The Pearson's chi-square test was used to compare categorical variables. The Cohen's kappa test was used to determine the level of compatibility between readers. Readers made independent evaluations of each other. ANOVA was applied to more than two variables by controlling the distributions in the comparison of continuous measurements between the groups. A statistical significance level was set at 0.05 in all tests.

## RESULTS

Between April 2013 and August 2018, 194 patients who applied to our hospital for pulmonary nodule research or other reasons were included in this study. In the study, 84 (43.3%) patients were female and 110 (56.7%) were male. The age range of the patients was between 18 and 83 years. The mean age of the patients was 58.35±15.29 years. The average size of nodules detected on CT was 10.67±7.23. Considering CT as the gold standard modality for the detection of nodules (1–30 mm) in this study, for the first reader, 135 (69.5%) nodules were detected in postcontrast T1 vibe images, 130 (67%) in T2 FSE, 128 (66%) in precontrast T1 vibe, and 98 (50.5%) nodules in the T2 TIRM sequence. For the second reader, 133 (68%) nodules were detected in postcontrast T1 vibe images, 120 (61.9%) in T2 FSE, 122 (62.9%) in precontrast T1 vibe, and 99 (51%) nodules in the T2 TIRM sequence. For both readers, the highest percentage of detection of nodules was observed in the postcontrast T1 vibe images and the lowest detection percentage in the T2 TIRM sequence. Capability levels were

examined in detecting nodules between the first and second readers, and the ratios of 0.92 in T2 FSE, 0.81 in postcontrast T1 vibe images, 0.93 in precontrast T1 vibe, and 0.96 in T2 TIRM sequence were obtained. According to both radiologists, the compatibility between the postcontrast T1 vibe, T2 FSE, and T2 TIRM sequences was very good. In the precontrast T1 vibe sequence, a medium level of capability was noted.

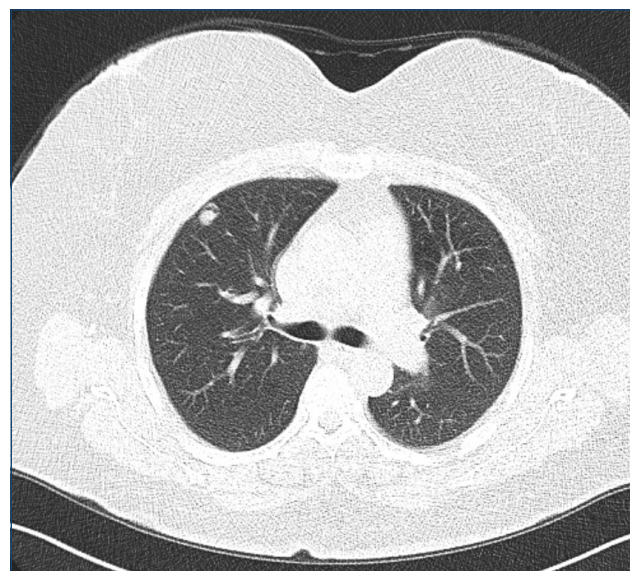
The percentages of readers to detect nodules between sequences, kappa compliance levels between readers, and the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for the study sequences are shown in Table 1.

In the follow-up of 194 nodules, 168 (86.6%) remained stable; therefore, a noninvasive intervention was performed. An invasive procedure was applied to 26 (13.4%) nodules. Pathological results showed 17 (8.7%) nodules as benign and 9 (4.6%) in a malignant nature. Histopathological results confirmed 7 (3.6%) nodules as metastasis and 2 (1%) as primary lung adenocarcinoma.

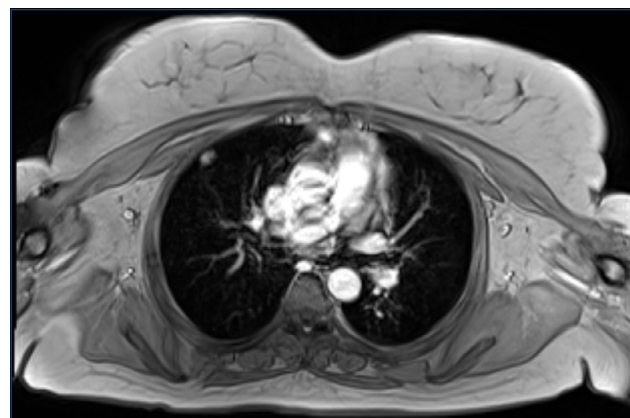
CT and MR images of a 44-year-old female patient are shown in Figures 1 and 2, respectively.

## DISCUSSION

With increasing research on the use of MRI in the detection of pulmonary nodules, a greater understanding of the limitations and areas of use has increased<sup>7</sup>. In this study, we aimed to determine which MRI sequences are easier to detect nodules. The findings showed that the highest nodules were detected in the T1 vibe sequence, attributing this to the fact that most of the nodules are solid, thereby causing a significant contrast difference from the pulmonary parenchyma, and that T1 vibe images can show very good edge sharpness.



**Figure 1.** Thoracic computed tomography of a 44-year-old female patient. A solid density nodule is observed in the right lung upper lobe anterior segment.



**Figure 2.** Magnetic resonance imaging of a 44-year-old female patient showing postcontrast T1 vibe sequence.

**Table 1.** Percentages of readers to detect nodules between sequences, kappa compliance levels between readers, and the sensitivity, specificity, positive predictive value, and negative predictive value for the study sequences.

		Group		Kappa	Sensitivity (95%CI)	Specificity (95%CI)	PPV (95%CI)	NPV (95%CI)
		Reader 1	Reader 2					
Postcontrast T1 vibe	Not seen	59 (30.4%)	61 (31.4%)	0.826	65.9% (58.8–72.6)	35.6% (30.8–40.6)	33.9% (31.1–36.7)	67.6% (62.3–72.6)
	Seen	135 (69.6%)	133 (68.6%)					
T2 FSE	Not seen	64 (33%)	74 (38.1%)	0.881	70.1% (63.1–76.5)	35.6% (30.8–40.6)	35.2% (32.6–38.0)	70.4% (64.9–75.4)
	Seen	130 (67%)	120 (61.9%)					
Precontrast T1 vibe	Not seen	66 (34%)	72 (37.1%)	0.525	71.7% (64.8–77.9)	30.9% (26.4–35.8)	34.2% (31.7–36.7)	68.6% (62.5–74.1)
	Seen	128 (66%)	122 (62.9%)					
T2 TIRM	Not seen	96 (49.5%)	95 (49%)	0.919	52.6% (45.3–59.8)	49.2% (44.1–54.3)	34.1% (30.5–37.9)	67.5% (63.4–71.3)
	Seen	98 (50.5%)	99 (51%)					

CI: confidence interval.

An MRI examination has been routinely used to detect mediastinal, chest wall, and vascular invasion of mass lesions due to its ability to provide high resolution for soft tissue. However, studies on diagnosis and follow-up of pulmonary nodules and lung parenchymal diseases are still ongoing. A multi-detector CT is considered the gold standard modality in diagnosis and follow-up. In addition, research on reducing radiation exposure is ongoing<sup>8,9</sup>. There are only a few indications that lung-mediastinal MRI replaces CT such as thoracic wall and mediastinal pathologies, vascular invasion, and its role in staging of oncological patients. Although CT provides optimal spatial resolution, it creates limited soft-tissue contrast. The use of MRI in the lung is limited by motion artifact (cardiac and respiratory origin), sensitivity artifact (due to multiple artifacts and interfaces), and low proton amount. However, it has advantages such as high resolution for soft tissue, the absence of ionizing beam, and not requiring a contrast agent in most examinations<sup>10</sup>. In this study, we first examined the detectability of the nodule, the degree of spatial and geometric resolution of MRI regardless of the size, and the differences and limits between sequences. We found the highest detection rate in the T1 vibe sequence for both readers, attributing this ratio to the higher spatial resolution of the T1 vibe sequence and hence the clearer edge sharpness. The vibe sequence is a 3D volumetric GRE sequence. This sequence produces T1-weighted 3D images using interpolation and/or partial Fourier techniques. Vibe sequences are a sequence that allows high-resolution imaging at a 30-s breath-hold time. Semelka et al stated that at a very high rate, nodules can be detected at a 3-mm threshold value in 3D GRE MRI sequences<sup>11</sup>. In our study, both readers detected the lowest rate of nodules in the T2 TIRM sequence, attributing this to the high rate of background noise in the lung tissue of the T2 TIRM sequence. TIRM sequences are inversion recovery sequences, regardless of longitudinal magnetization phase/polarity.

## REFERENCES

1. Midthun DE, Swensen SJ, Jett JR. Approach to the solitary pulmonary nodule. *Mayo Clin Proc.* 1993;68(4):378-85. [https://doi.org/10.1016/s0025-6196\(12\)60136-0](https://doi.org/10.1016/s0025-6196(12)60136-0)
2. Winer-Muram HT. The solitary pulmonary nodule. *Radiology.* 2006;239(1):34-49. <https://doi.org/10.1148/radiol.2391050343>
3. Zerhouni EA, Stitik FP, Siegelman SS, Naidich DP, Sagel SS, Proto AV, et al. CT of the pulmonary nodule: a cooperative study. *Radiology.* 1986;160(2):319-27. <https://doi.org/10.1148/radiology.160.2.3726107>
4. Holin SM, Dwork RE, Glaser S, Rikli AE, Stocklen JB. Solitary pulmonary nodules found in a community-wide chest roentgenographic survey: a five-year follow-up study. *Am Rev Tuberc.* 1959;79(4):427-39. <https://doi.org/10.1164/artpd.1959.79.4.427>
5. Bateson EM. An analysis of 155 solitary lung lesions illustrating the differential diagnosis of mixed tumors of the lung. *Clin Radiology.* 1965;16(1):51-65. [https://doi.org/10.1016/s0009-9260\(65\)80033-2](https://doi.org/10.1016/s0009-9260(65)80033-2)

However, it may be an advantage to observe pronounced hyperintense in nodules with high fluid content in T2-weighted images. We noticed that the use of contrast agents in the T1 vibe sequence did not make a statistically significant difference in detecting nodules for both readers. In a study of oncological patients with lung nodules, the T2-weighted PROPELLER sequence showed no statistically significant difference in detecting nodules 10 mm or larger from HRCT<sup>12</sup>.

The limitations of our study are the inability to optimize the image quality and artifacts secondary to retrospective scanning and to include patients with an optimal number of nodules for each subgroup. The longer duration of MRI examination compared to CT has caused an increase in arteries and difficulties in the study, especially in patients who have difficulties in respiratory control. Another limitation is the possibility of differences in the CT dimensions of the nodules due to the acquisition of images by CT and HRCT techniques.

## CONCLUSION

In this study, which we conducted with two different readers, one of whom was an experienced thoracic radiologist, to detect pulmonary nodules by MRI, both readers detected the highest rate in the T1 vibe sequence and the lowest rate in the T2 TIRM sequence. In addition, the kappa compatibility levels were very good in the postcontrast T1 vibe and T2 FSE sequences.

## AUTHORS' CONTRIBUTIONS

**HAK:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **AK:** Supervision. **OD:** Conceptualization, Data curation. **KK:** Formal Analysis. **FA:** Supervision.

6. Murthy SC, Rice TW. The solitary pulmonary nodule: a primer on differential diagnosis. *Semin Thorac Cardiovasc Surg.* 2002;14(3):239-49. <https://doi.org/10.1053/stcs.2002.34450>
7. Kurihara Y, Matsuoka S, Yamashiro T, Fujikawa A, Matsushita S, Yagihashi K, et al. MRI of pulmonary nodules. *AJR Am J Roentgenol.* 2014;202(3):W210-6. <https://doi.org/10.2214/AJR.13.11618>
8. Wormanns D. Abklärung von Lungenrundherden: Management durch Früherkennungsuntersuchungen detektierter pulmonaler Rundherde [Diagnostic work-up of pulmonary nodules: management of pulmonary nodules detected with low-dose CT screening]. *Radiologe.* 2016;56(9):803-9. German. <https://doi.org/10.1007/s00117-016-0150-6>
9. Ohno Y, Koyama H, Seki S, Kishida Y, Yoshikawa T. Radiation dose reduction techniques for chest CT: principles and clinical results. *Eur J Radiol.* 2019;111:93-103. <https://doi.org/10.1016/j.ejrad.2018.12.017>
10. Vogt FM, Herborn CU, Hunold P, Lauenstein TC, Schröder T, Debatin JF, et al. HASTE MRI versus chest radiography in the detection of pulmonary nodules: comparison with MDCT. *AJR Am J Roentgenol.* 2004;183(1):71-8. <https://doi.org/10.2214/ajr.183.1.1830071>

11. Semelka RC, Cem Balci N, Wilber KP, Fisher LL, Brown MA, Gomez-Caminero A, et al. Breath-hold 3D gradient-echo MR imaging of the lung parenchyma: evaluation of reproducibility of image quality in normals and preliminary observations in patients with disease. *J Magn Reson Imaging*. 2000;11(2):195-200. [https://doi.org/10.1002/\(sici\)1522-2586\(200002\)11:2<195::aid-jmri18>3.0.co;2-q](https://doi.org/10.1002/(sici)1522-2586(200002)11:2<195::aid-jmri18>3.0.co;2-q)
12. de Galiza Barbosa F, Geismar JH, Delso G, Messerli M, Huellner M, Stolzmann P, et al. Pulmonary nodule detection in oncological patients - Value of respiratory-triggered, periodically rotated overlapping parallel T2-weighted imaging evaluated with PET/CT-MR. *Eur J Radiol*. 2018;98:165-70. <https://doi.org/10.1016/j.ejrad.2017.11.010>

