



Comparison of Ultrashort TE Lung MRI and HRCT Lungs for Detection of Pulmonary Nodules in Oncology Patients

Gopinath Periaswamy¹ Venkatesh Kasi Arunachalam¹ Rajeshkumar Varatharajaperumal¹
Gobi Kalyan¹ Rajesh Selvaraj¹ Pankja Mehta¹ Mathew Cherian¹

¹Department of Radiology, Kovai Medical Center and Hospital, Coimbatore, Tamil Nadu, India

Address for correspondence Venkatesh Kasi Arunachalam, DMRD, DNB, FRCR, MOI, Department of Radiology, KMCH, Avانشi Road, Coimbatore, Tamil Nadu, 641014, India
(e-mail: drkasivenkatesh@yahoo.co.in; radvenki79@gmail.com).

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Abstract

Purpose The purpose of this study is to evaluate the detection rate of pulmonary nodules in ultrashort echo time (UTE) lung magnetic resonance imaging (MRI) and to compare it with computed tomography (CT) in oncology patients.

Materials and Methods All individuals undergoing radiotherapy/chemotherapy/regular follow-up or visiting the oncology department and referred to radiology department for nodule detection, during the period of 1 year, were subjected to UTE lung MRI using the sequence Flash 3d_spiralvibe coronal 1.25 mm iso and high-resolution CT lungs and the images were analyzed.

Results Among the total number of nodules detected in both lungs of all patients, nodules detected by CT were 241, and nodules detected by MRI were 212. The nodule detection rate by MRI was 87.96%. The detection rate of nodules for size equal to or more than 5 mm was nearly 100%. For nodules less than 5 mm, and equal to or more than 4 mm, MRI showed a comparable detection rate of 75%, while for nodules less than 4 mm, the detection rate was only 25%.

Conclusion Our study results indicate that lung MRI had a near-complete detection rate for nodules equal to or more than 5 mm in size. Hence, in oncology patients who are undergoing regular follow-up of the lung nodules, lung MRI using UTE can replace low-dose CT, which in turn reduces the radiation dose to the patient.

Keywords

- ▶ pulmonary nodules
- ▶ ultrashort TE lung MRI
- ▶ oncology
- ▶ HRCT lungs

Introduction

A lung nodule is defined as a relatively well-marginated rounded opacity measuring up to 3 cm in diameter. Pulmonary nodules are common, and as the spatial resolution of computed tomography (CT) scanners has improved, detection of smaller nodules has become more common, which are more often incidental lung nodules.

Pulmonary nodules are classified according to size, into miliary opacities (<2 mm), pulmonary micronodules

(2–7 mm), pulmonary nodules (7–30 mm), and pulmonary mass (>30 mm). In addition, the nodules are classified into solid, partly solid, and ground glass pulmonary nodules based on morphology. They are further classified into perilymphatic, centrilobular, and random pulmonary nodules based on the distribution.¹

Magnetic resonance imaging (MRI) is a promising technique for the longitudinal evaluation of pulmonary diseases and functions and may provide an alternative to low-dose CT

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(LDCT) for lung cancer patients. However, a major issue with lung MRI is its susceptibility to the effects of respiratory motion. Therefore, respiratory gating or a breath-hold maneuver is performed during image acquisition to minimize the impact of respiratory motion. Besides respiration motion, structural lung MRI has been limited historically because of the low proton density of the lung parenchyma and short $T2^*$ values at the air-tissue interface requiring rapid data sampling after spin excitation and maximizing k-space coverage while minimizing acquisition time. The recently developed MRI ultrashort echo time (UTE) technique allows an echo time (TE) shorter than 200 μ s, which improves the evaluation of pulmonary disease and pulmonary malignancies.²

UTE MRI has demonstrated acceptable diagnostic image quality and high interreader agreement for pulmonary nodule detection, making it a potential alternative to LDCT in lung cancer screening. A feasibility study conducted in oncology patients suggested that the high sensitivity, shorter scan duration, and satisfactory image quality of free-breathing spiral three-dimensional (3D) UTE improved detection of pulmonary nodules.² More sensitive detection of small nodules sized 4 to 8 mm was achieved with free-breathing.² Additional studies are needed to evaluate UTE MRI in cancer patients with very small nodules.

The UTE sequence used in the present study is a 3D variable-TE UTE stack-of-spirals sequence at 3 T, composed of sequences with a 3D spoiled gradient-echo and stack-of-spirals acquisition. This UTE sequence can achieve very short TE by beginning each spiral readout immediately after the through-plane phase-encoding gradient waveform has completed, which captures the rapidly decaying lung parenchymal signal in a short time without compromising diagnostic image quality.

The main concerns in LDCT lung cancer screening by National Lung Screening Trial (NLST)¹ are high false-positive rates associated with malignancy (23%) and exposure to ionizing radiation. The UTE sequence may begin a new era of pulmonary metastasis workups for oncology patients. The purpose of this study is to compare the detection rate of lung nodules by UTE lung MRI with high-resolution CT (HRCT), and evaluate the diagnostic accuracy of MRI in lung nodules of different sizes.

Materials and Methods

Methodology

- The study was performed in a multispecialty, National Accreditation Board for Hospitals & Healthcare Providers (NABH)-accredited tertiary care hospital in India. Approval of the thesis was taken by the Institutional Ethical Committee and the study was performed according to standard protocols.
- All oncology patients who were coming for screening of pulmonary nodules for a 1-year period.
- MRI technique: Imaging was performed on a 3T Siemens Skyra scanner. MRI sequence and parameters used are detailed in ►Table 1.

Table 1 MRI sequence and parameters used in the study

Sequence	FI3d_spiralvibe cor 1.25 mm iso
TR (ms)	3.53
TE (ms)	0.05
FoV (mm)	600
FoV (%)	100
Slices per slab	192
Slice thickness (mm)	1.25
Distance factor (%)	20
Voxel size (mm)	1.3 × 1.3 × 1.3
Coil	Body surface coil
Respiration	Free-breathing sequence

Abbreviations: FoV, field of view; MRI, magnetic resonance imaging; TE, echo time; TR, repetition time.

- CT Technique: Imaging was performed with GE Bright speed 16 slice CT scanner. Parameters included are: helical scan type, kV ranges 120 to 140, tube rotation time 0.8 second, detector configuration 16 × 1.25 mm, collimation 0.625 to 10 mm, pitch 1.75, and mAS ranges from 100 to 350.

Inclusion Criteria

All individuals undergoing radiotherapy/chemotherapy/regular follow-up or visiting the oncology department and referred to the radiology department for nodule detection were included in this study.

Exclusion Criteria

- General contraindications for MRI.
- Patient not willing to give consent.
- Suboptimal image quality due to patient movement during image acquisition.

It is a cross-sectional study and sample size calculation was done in N Master 2.0 software as 72 nodules.

Results

In this study of comparison of UTE lung MRI and HRCT lungs for detection of pulmonary nodules in oncology patients, 50 patients were subjected to HRCT lungs and UTE lung MRI using the sequence FI3d_spiralvibe cor 1.25 mm iso.

The HRCT and MRI images were analyzed 1 week apart to remove observer bias. The images were assessed by a board-certified radiologist with 15 years of experience in cross-sectional imaging. The number and size of lung nodules in each lobe of both lungs were evaluated, and data were collected in MS Office Excel 2010.

The collected data were analyzed with IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp, Armonk, New York, United States). To describe the data, descriptive statistics, frequency analysis, and percentage analysis were used for categorical variables, and the mean and standard deviation were used for continuous variables.

The mean age of the sample group was 59 years. Among 50 patients, 33 were males. The majority of patients had no known primary malignancy at the time of imaging, who had presented with metastatic disease with an unknown primary malignancy and were evaluated for detection of primary malignancy and lung metastasis. Among the cases of known primary malignancy, the majority was metastasis from breast cancer, renal cell carcinoma, and carcinoma lung.

Among the total number of nodules detected in both lungs of all patients, nodules detected by CT were 241, and nodules detected by MRI were 212. The nodule detection rate by MRI was 87.96%. The number of nodules detected by CT and MRI and detection rate of nodules by MRI are detailed in ►Table 2.

Comparison of Nodule Size Detected by CT and MRI

For Nodules Equal to or More Than 3 mm to Less Than 4 mm (►Fig. 1)

The correlation coefficient for nodules equal to or more than 3 mm to less than 4 mm between CT and MRI was 0.2073 (►Fig. 2) and *p*-value was 0.0012. Although it was a positive correlation, since the *r* value was smaller, the correlation was weak.

For Nodules Equal to or More Than 4 mm to Less Than 5 mm (►Fig. 3)

The correlation coefficient for nodules equal to or more than 4 mm to less than 5 mm between CT and MRI was 0.6921

Table 2 Comparison of nodule detection rate between CT and MRI

Size of the nodules	No. of nodules in CT	No. of nodules in MRI	Nodule detection rate by MRI
≥3 mm to <4 mm	32	8	25%
≥4 mm to <5 mm	16	12	75%
≥5 mm to <7 mm	58	57	98.3%
≥7 mm to <10 mm	50	50	100%
≥ 10 mm	85	85	100%
Overall nodules	241	212	87.9%

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

(►Fig. 4) and *p*-value was less than 0.0001. Since the *r* value was higher, a moderate positive correlation was noted.

For Nodules Equal to or More Than 5 mm to Less Than 7 mm (►Figs. 5, 6)

The correlation coefficient for nodules equal to or more than 5 mm to less than 7 mm between CT and MRI was 0.5464 (►Fig. 7) and *p*-value was less than 0.0001. Since the *r* value was higher, a moderate positive correlation was noted.

For Nodules Equal to or More Than 7 mm (►Fig. 8)

The correlation coefficient for nodules equal to or more than 7 mm between CT and MRI was 0.9941 (►Fig. 9) and *p*-value

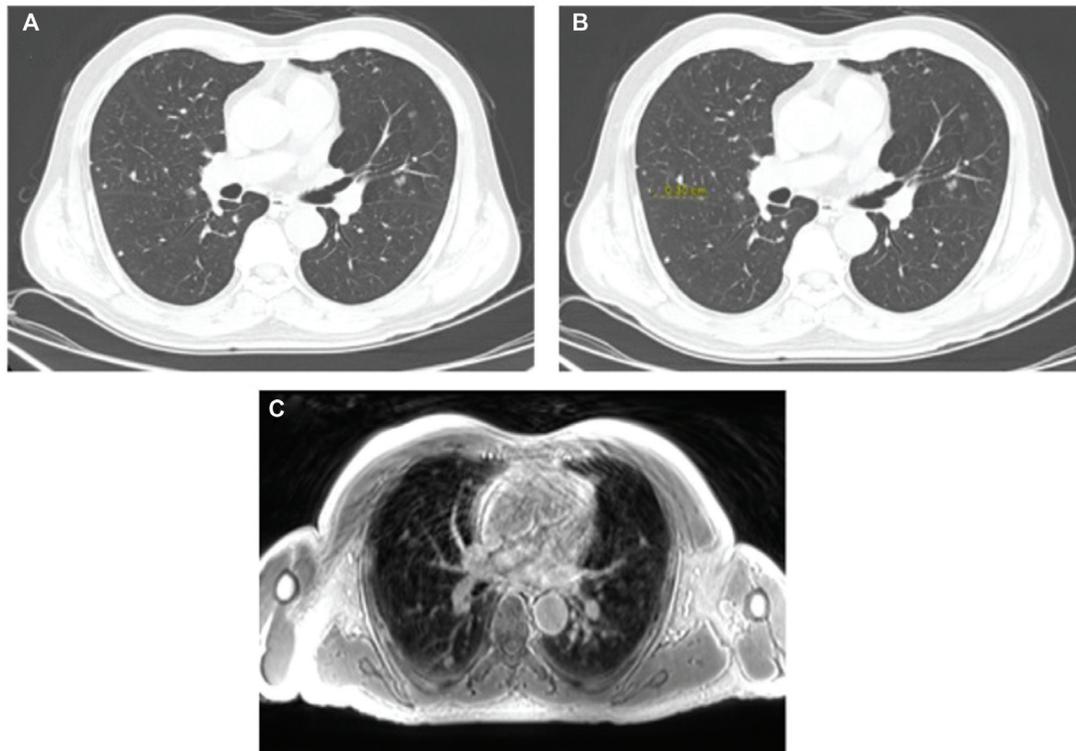


Fig. 1 Axial sections of computed tomography chest (A, B) show a 3 mm nodule detected in right upper lobe, which could not be detected in magnetic resonance imaging (MRI) thorax-three-dimensional ultrashort echo time image. (C) Few other micronodules (A, B) are also seen scattered in lung parenchyma, which could not be detected in MRI thorax.

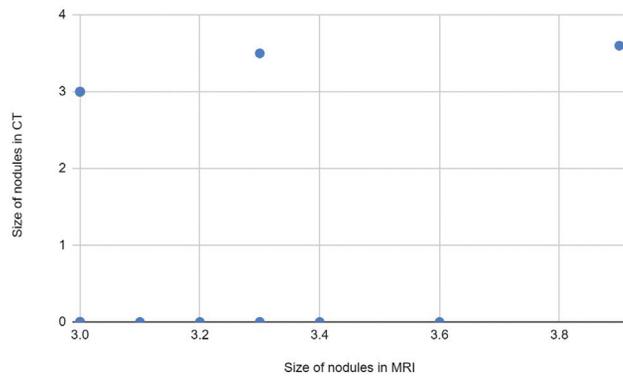


Fig. 2 Scatter plot for nodules equal to or more than 3 mm to less than 4 mm. CT, computed tomography; MRI, magnetic resonance imaging.

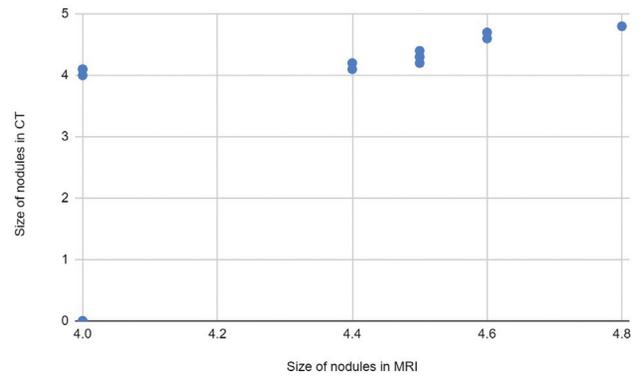


Fig. 4 Scatter plot for nodules equal to or more than 4 mm to less than 5 mm. CT, computed tomography; MRI, magnetic resonance imaging.

was less than 0.0001. Since the r value was close to 1, a strong positive correlation was noted.

For Overall Number of Nodules

The correlation coefficient for overall nodules between CT and MRI was 0.9809 (\rightarrow Fig. 10) and p -value was less than 0.0001. Since the r value was high, a strong positive correlation was noted.

Discussion

In this study, the comparison of UTE lung MRI and HRCT lungs for detection of pulmonary nodules in oncology patients using the sequence FI3d_spiralvibe cor 1.25 mm iso was performed. There were no apparent detection rate discrepancies among the lung lobes. The detection rate among the right middle lobe was comparatively low because

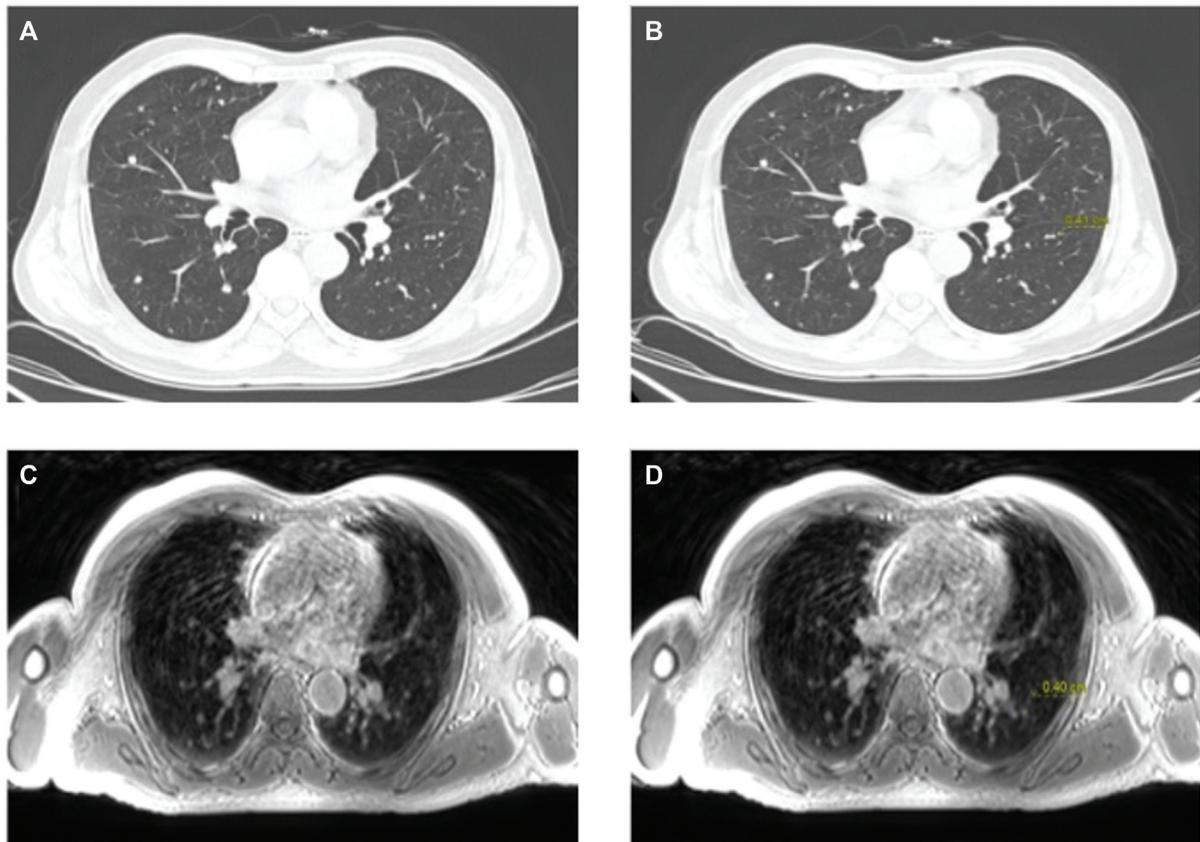


Fig. 3 Axial sections of computed tomography chest (A, B) and magnetic resonance imaging (MRI) thorax-three-dimensional ultrashort echo time images (C, D) show a 4 mm nodule detected in the superior segment of left lower lobe. Few other micronodules (A, B) are also seen scattered in lung parenchyma, which could not be detected in MRI thorax.

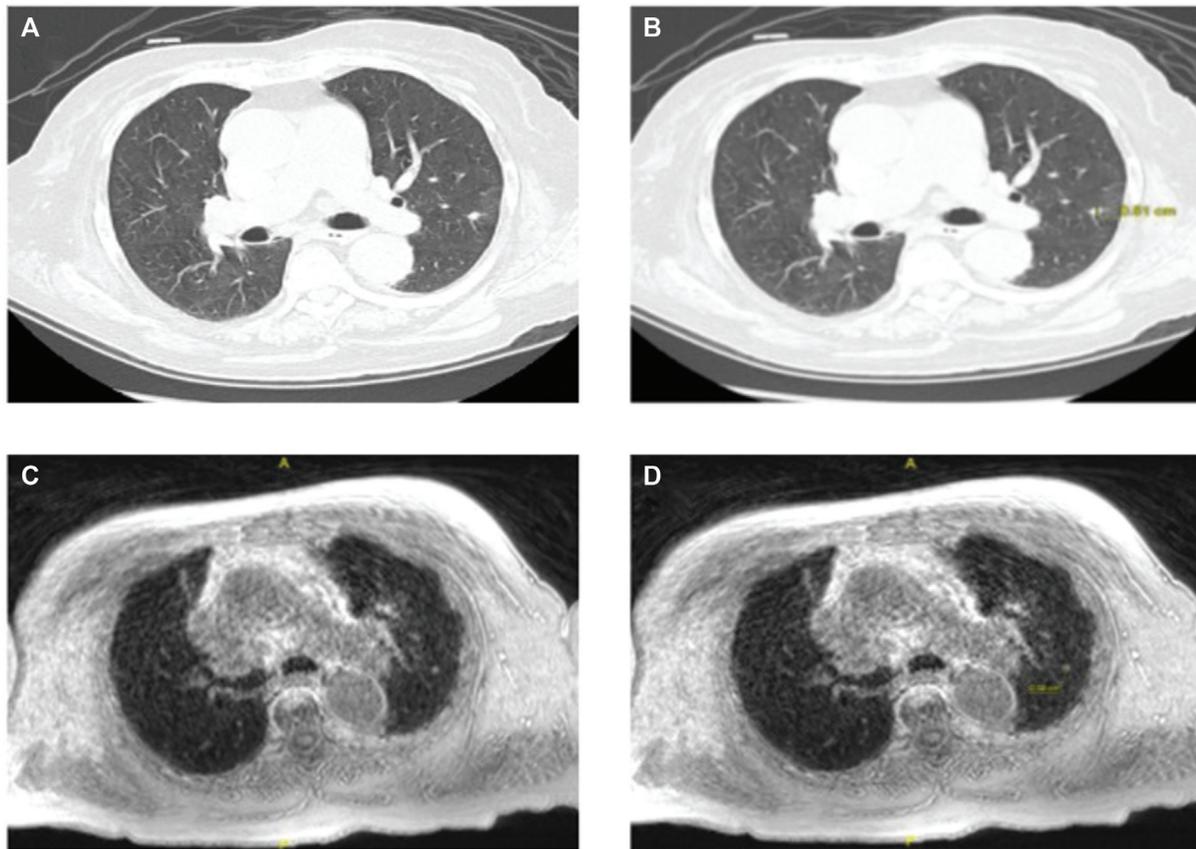


Fig. 5 Axial sections of computed tomography chest (A, B) and magnetic resonance imaging thorax-three-dimensional ultrashort echo time images (C, D) show a 5 mm nodule detected in the left upper lobe.

the sample had smaller-size nodules predominantly in that lobe. In larger nodules, there were no apparent differences in the detection rate among the lung lobes.

In our study, nodules less than 3 mm were not considered since they are considered as micronodules.³ The detection rate of nodules for size equal to or more than 5 mm was nearly 100%. The nodules of size equal to or more than 5 mm detected by CT were 193, and the nodules detected by MRI were 192. Only one nodule of size 5 mm was not detected by MRI, which was due to an artifact in the apical segment of the right upper lobe.

For nodules less than 5 mm, and equal to or more than 4 mm, MRI showed a comparable detection rate of 75%, while for nodules less than 4 mm, the detection rate was only 25%.

The correlation coefficient for equal to or more than 7 mm was showing strong correlation; for nodules between 5 and 7 mm and 4 and 5 mm, there was moderate correlation, and for nodules between 3 and 4 mm there was weak correlation.

It was worth noting that the risk of cancer in nodules smaller than 5 mm is extremely low, ranging between 0 and 1%.^{4,5} The prevalence of lung cancer among the patients with 4 to 6 mm nodules was also extremely low in the NLST: 0.49% (18 out of 3,668 patients) at baseline, 0.3% (12 out of 3,882 patients) in the first screening round, and 0.7% (15 out of 2,023 patients) in second phase of screening.^{1,6} Furthermore, in the Dutch-Belgian Randomized Lung Cancer Screening

Trial (NELSON study) research, the risk of malignancy was equal in participants with nodules measuring less than 5 mm or 100 mm³ and without nodules. Taking these observations into account, the nodule size criterion (diameter or volume) for evaluating the requirement for follow-up has been increased to 5 mm or 80 mm³ for British Thoracic Society (BTS) guidelines and 6 mm or 100 mm³ for Fleischner Society standards, according to the most recent guidelines. Even when identifying lung nodules based on their density, data from the literature confirmed the above-described link between nodule size and malignancy. The Early Lung Cancer Screening Project and the Mayo Clinic CT screening trial found a $\leq 1\%$ malignancy risk in solid nodules less than 5 mm in diameter, while the majority (80%) of malignancies was larger than 8 mm in diameter.⁷⁻¹⁰

In our study, the nodule detection rate for nodules less than 5 mm is 50%. However, according to Fleischner Society and BTS recommendation guidelines, the probability of nodules less than 5 mm turning malignant is less. Hence, the lesser detection rate of nodules less than 5 mm in our study is not going to significantly affect the prognosis.

According to Fleischner Society guidelines, the nodules are managed according to their density, size, number of nodules (single or multiple), and the patient's cancer risk. CT follow-up in 3 months is recommended for solid nodules less than 8 mm. Positron emission tomography-CT or tissue

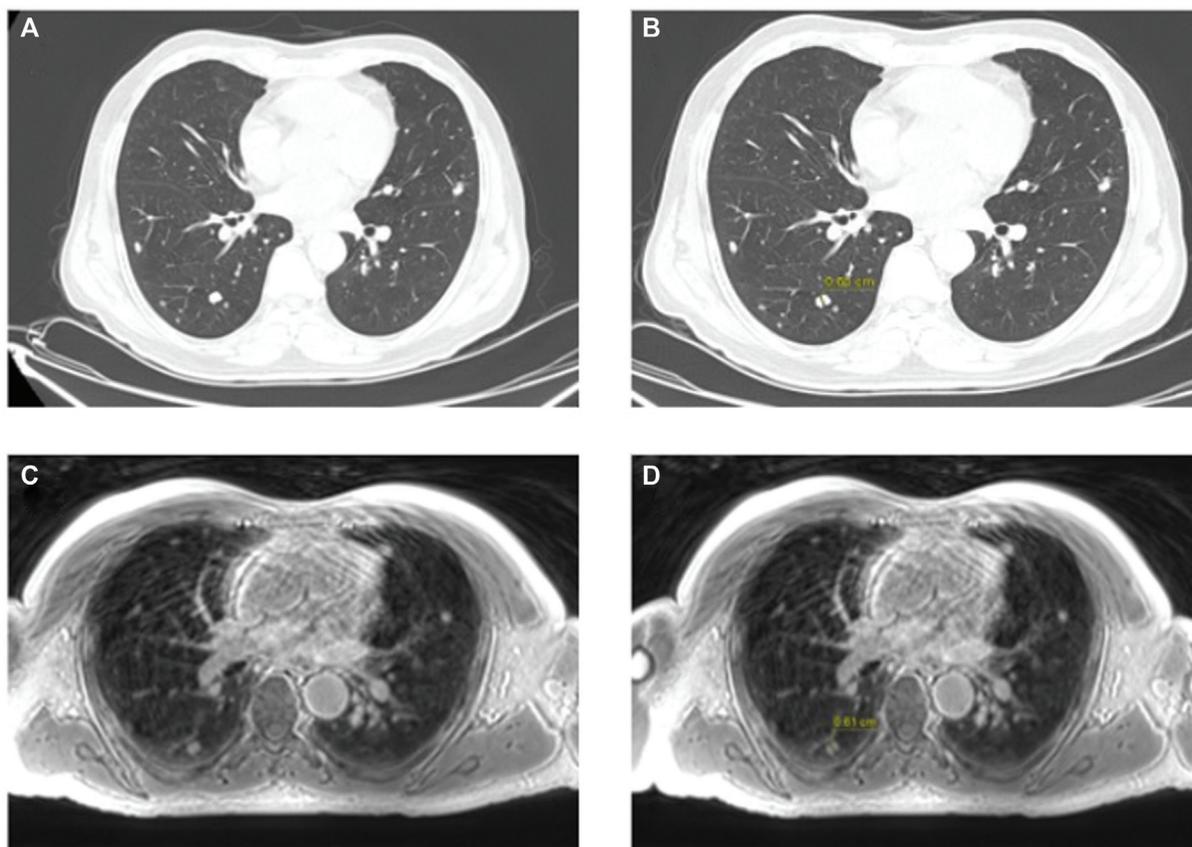


Fig. 6 Axial sections of computed tomography chest (A, B) and magnetic resonance imaging thorax-three-dimensional ultrashort echo time images (C, D) show a 6 mm nodule detected in the superior segment of right lower lobe.

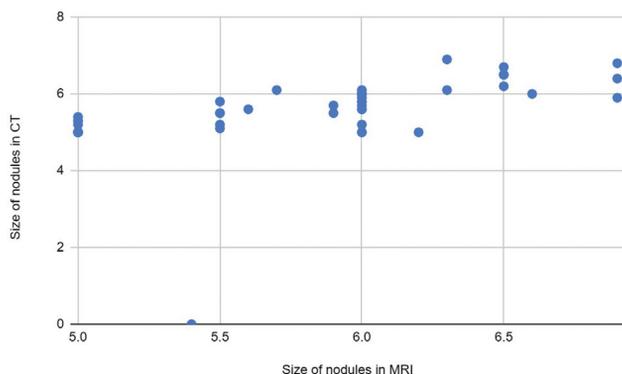


Fig. 7 Scatter plot for nodules equal to or more than 5 mm to less than 7 mm. CT, computed tomography; MRI, magnetic resonance imaging.

sampling is recommended for nodules greater than 8 mm. The decision to set the cut-off at 8 mm was made based on the risk of malignancy.¹¹ The duration of surveillance is determined by the initial nodule size and the patient risk. The larger the diameter of the nodule, the greater the patient's risk and suggested shorter time interval for follow-up. The follow-up procedure for pulmonary nodules smaller than 8 mm will be determined by the patient's risk (high or low) and whether the size is below 6 mm or between 6 and 8 mm. The CT follow-up might last between 3 and 24 months, depending on the patient's risk.

There are no particular guidelines for nodules in patients with a history of oncologic illness in any of these guidelines. Oncologic patients are typically excluded from most guidelines, making the management of nodules in this patient group extremely difficult. According to a recent survey, radiologists tend to report every detected nodule and to routinely recommend follow-up CT examinations in oncologic patients.¹² In this situation, 75.84% of responders urge a short-term follow-up CT for any incidentally found nodule, with the size of the nodule being the most critical determinant in establishing follow-up intervals.¹² Baseline nodules (prevalent) have a lower malignancy risk in oncologic patients than new or incident (not incidental) nodules, just as they do in nononcologic individuals.¹³ In oncologic patients, prevalent nodules are common, and many of them are benign. In patients with colorectal cancer, the prevalence of indeterminate pulmonary nodules on staging chest CT ranged from 4 to 42%, with the majority (70%) having no clinical relevance.¹⁴ Other than the size of the nodule, the number of nodules, contour irregularity, and the presence of pleural studding are the other radiological criteria that are used to raise the likelihood of malignancy in patients with cancer.¹⁵ In a study by Munden et al, in oncologic patients, they found that 28% of small nodules detected at initial CT increased in size in the follow-up CT, suggesting metastasis.¹⁶ Because metastases have a shorter

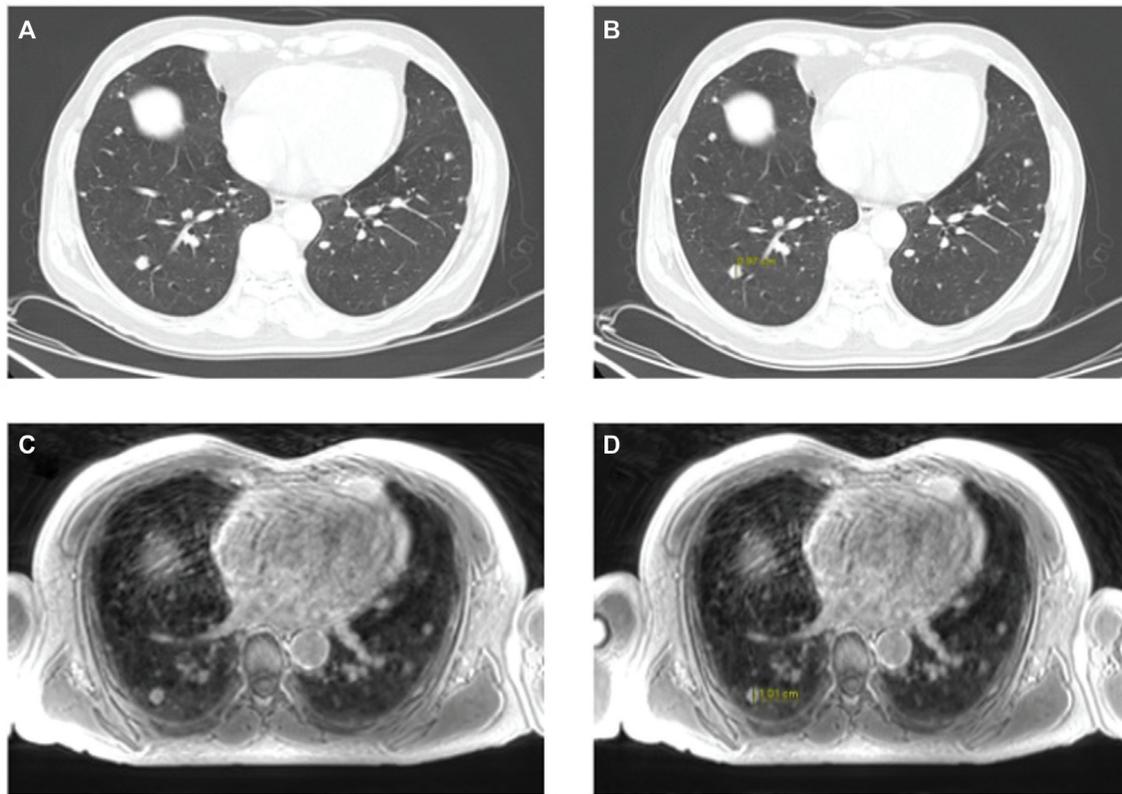


Fig. 8 Axial sections of computed tomography chest (A, B) and magnetic resonance imaging thorax-three-dimensional ultrashort echo time images (C, D) show a 10 mm nodule detected in the superior segment of right lower lobe.

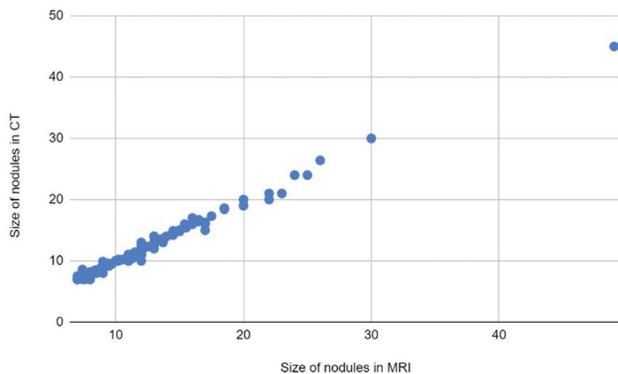


Fig. 9 Scatter plot for nodules equal to or more than 7 mm. CT, computed tomography; MRI, magnetic resonance imaging.

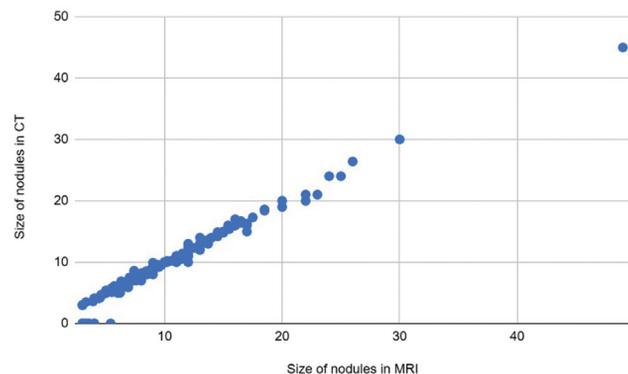


Fig. 10 Scatter plot for overall nodules. CT, computed tomography; MRI, magnetic resonance imaging.

volume doubling time (VDT), the standard advice for oncologic patients is a 3 to 6 monthly follow-up.

MRI thorax sequences are susceptible to minimal motion artifacts and hence likely to result in reduced spatial resolution when compared with the LDCT images, which could hinder the diagnostic ability of MRI; however, this was noted only in the case of nodules with size less than or equal to 4 mm in our study. In the evaluation of nodules more than 4 mm, MRI was noted to have a diagnostic ability at par with CT. To avoid missing a small metastasizing nodule, LDCT is the appropriate imaging modality for initial screening. The rest of the follow-up imaging can be performed with MRI at short intervals (2 months). This results in a decrease in radiation dose to the oncologic patients on regular follow-

up. Since the doubling time of infection and rapidly growing metastasis is short, MRI scanning at shorter intervals will pick up the small metastatic nodules at the earliest.

Limitations

1. The patient population of our prospective study was limited. Larger studies are necessary to confirm the results.
2. Histological or morphological characteristics of the nodules were not assessed or compared.
3. Our results are currently only valid to FI3d_spiralvibe cor 1.25 mm iso sequence by Siemens in 3T machine and cannot be automatically translated to other vendors.

4. MRI lung sequence is susceptible to minimal motion artifacts and hence resulted in reduced spatial resolution when compared with the LDCT images.
5. Nodules less than 4 mm had decreased detection rate in MRI.

Conclusion

Our study results indicate that lung MRI had a near-complete detection rate for nodules equal to or more than 5 mm in size, a reasonable detection rate for nodules between 4 and 5 mm, but a lesser detection rate for nodules less than 4 mm. "Since the smallest nodule could have a clinical significance in oncology patients, baseline imaging in such patients should be preferably LDCT, and further follow-ups can be done with UTE lung MRI that can reduce the radiation dose to the oncology patients. Since the VDT of metastatic nodules is small, MRI at short intervals is suggested for detection of small new nodules that can upstage the disease."

Conflicts of Interest

None.

Source of Funding

None.

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