Diagnostic importance of maximum intensity projection technique in the identification of small pulmonary nodules with computed tomography

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ABSTRACT

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Introduction: *In this retrospective study, the aim is to determine the sensitivity of maximum intensity projection (MIP) technique to 3 mm-thick axial sections in patients with small pulmonary nodules identified via examination using computed tomography (CT), and to identify whether this technique provides significant reduction in duration of nodule evaluation.*

Materials and Methods: *A total of 69 patients (339 nodules) who underwent thoracic tomography due to various complaints and in whom pulmonary nodules were identified as a result of the examination were included in the study. Their axial sections that are 3 mm-thick and MIP sections obtained in the axial plane were evaluated by two different radiologists at different times by keeping time. The dimensions and evaluation times of the nodules were recorded separately for each method.*

Results: *Evaluation compatibility between the radiologists was found to be 86.8% and it was considered to be perfectly compatible. Sensitivity of the 1st radiologist in the detection of nodules with MIP was 81.4%, whereas the sensitivity of the 2nd radiologist was 83.4%. In the evaluation for the reporting periods, when the duration of evaluation of MIP images were compared with the gold standard, a statistically significant reduction was found in the reporting times of both radiologists (p< 0.01).*

Conclusion: *It was found that utilization of MIP images as an alternative method to detect pulmonary modules reduces the duration of evaluation significantly and provides the ability to detect nodules with high sensitivity. According to these data, MIP imaging may be preferred as an adjunct method in the evaluation of lung nodules as it provides fast and reliable information besides classical axial sections.*

Key words: *Pulmonary nodules; computed tomography; maximum intensity projection*

ÖZ

Küçük boyutlu akciğer nodüllerinin bilgisayarlı tomografi ile saptanmasında maksimum intensite projeksiyon tekniğinin önemi

Giriş: *Bu retrospektif çalışmada bilgisayarlı tomografi incelemesi ile küçük boyutlu pulmoner nodül saptanan hastalarda, "Maximum Intensity Projection (MIP)" tekniğinin, 3 mm'lik aksiyel kesitlere göre duyarlılığının saptanması ve bu tekniğin nodül değerlendirme süresinde anlamlı düzeyde süre kısalması sağlayıp sağlamadığını belirleyebilmektir.*

Materyal ve Metod: *Çeşitli şikayetlerle toraks tomografisi çekilen ve değerlendirme sonucu akciğer nodülü saptanan 69 (339 nodül) hasta çalışmaya dahil edildi. Hastaların 3 mm kalınlıktaki aksiyel kesitleri ile aksiyel planda alınan MIP kesitleri farklı zamanlarda süre tutularak, ayrı ayrı iki radyolog tarafından önceki raporları dikkate alınmadan değerlendirildi. Nodüllerin boyutları ve değerlendirme süreleri her bir yöntem için ayrı olarak kayıt edildi.*

Bulgular: *Radyologlar arası değerlendirme uyumu %86.8 saptanmış olup mükemmel uyumlu bulunmuştur. Birinci radyoloğun MIP ile nodül tespitindeki duyarlılığı %81.4 iken, ikinci radyoloğun duyarlılık düzeyi %83.4 olarak saptanmıştır. Raporlama süreleri açısından yapılan incelemede MIP görüntülerini değerlendirme sürelerinin altın standartla karşılaştırıldığında her iki radyolog için de raporlama sürelerinde istatistiksel olarak anlamlı düzeyde kısalma bulunmuştur (p< 0.01).*

Sonuç: *Akciğer nodüllerinin saptanmasında alternatif bir yöntem olarak MIP görüntüler kullanılmasının değerlendirme süresini anlamlı derecede kısalttığı ve yüksek duyarlılıkta nodül saptama özelliği gösterdiği saptanmıştır. Bu verilere göre MIP görüntüleme, akciğer nodüllerinin değerlendirilmesinde klasik aksiyel kesitler yanında, hızlı ve güvenilir bilgi vermesi nedeniyle yardımcı yöntem olarak tercih edilebilecektir.*

Anahtar kelimeler: *Pulmoner nodüller; bilgisayarlı tomografi; maksimum intensite projeksiyon*

INTRODUCTION

Pulmonary nodule is one of the most important pulmonary pathologies, with round or oval parenchymal lesions less than 3 cm in diameter which are surrounded by lung parenchyma (1).

Computed tomography (CT) is the imaging modality with the highest sensitivity that is most frequently used in the detection and follow up of pulmonary nodules today (2). Small pulmonary nodules in particular can be missed during the evaluation due to atypical localization or vascular neighborhood primarily because of the CT techniques and thus can be overlooked by the radiologist. Although it theoretically makes sense to thin out the section thickness to increase the sensitivity of CT to detect the small nodules, evaluation of many sections generated by this method by a single radiologist increases the probability of overlooking the nodules and causes the duration of evaluation to increase (3). In the recent years, maximum intensity projection (MIP) method, a CT imaging software where three or four of the axial sections obtained during the routine CT evaluation are combined and reformatted and thick sections (slabs) in which formations with high density are

highlighted, has started to be used and is becoming increasingly common. Unlike original axial images, this method accentuates the contrast between the nodule and surrounding parenchyma and contributes to the noticeability of the nodule in the detection of pulmonary nodules (4,5).

The aim of this study is to determine the level of sensitivity of MIP technique in the detection of small pulmonary nodules and to investigate whether the potential reduction provided by this technique in the duration of nodule evaluation is significant.

MATERIALS and METHODS

Patients

Approval of the local ethics committee was obtained for this study. Patients who underwent thorax CT due to various indications and were found to have pulmonary nodules between April 2012 and December 2012 were selected based on the retrospective evaluation of their thorax CT reports for a re-evaluation. In order for an easy interpretation of the nodules, mostly the patients with nodules with a diameter between 4-10 mm were preferred. Based on this, a total of 69 patients, 37 (54%) of which are female and 32 (46%)

of which are male, with ages between 22-87 (mean age 56 ± 12.65 years), who have images in PACS archiving system, were included in the study.

Computer Tomography Technique

Attention was paid to evaluate all patients with the same CT device (Sensation 16, Siemens). It was found that thorax CT evaluations in all cases was performed on 3 mm section thickness, using approximately 100 kV, 120 mAs protocol. In order to re-evaluate the images, 3 mm-thick routine images and MIP images obtained using these images were uploaded to the workstation (Leonardo Multimodality Workstation, Siemens) where the re-evaluation will be performed. To evaluate areas of parenchyma, standard lung parenchyma window settings were used (window level – 700 HU, window width 1.200 HU). However, no limitations were made for the readers to manipulate the window settings when evaluating the images.

Image Analysis

Prior to re-evaluation, it was decided that nodules larger than 10 mm and smaller than 4 mm in diameter or nodules with issues such as fibrosis, sequela changes or atelectasia accompanying the nodule will not be evaluated. As nodules smaller than 4 mm in diameter does not require follow-up except in high risk patients as recommended in Fleschner Classification, and MIP imaging provides and exaggerated image of the nodules and creates difficulties in distinguishing sequela and nodules, these were not included in the evaluation based on the joint decision of both observers. No time limitations were applied during the evaluation of the images. However, time was kept using a chronometer during the evaluation of the case images. Chronometer was started when the radiologists started the evaluation and chronometer was stopped when the nodule evaluation finished, and the evaluation durations were recorded.

Cases were performed by two radiologists with at least 15 years of experience in thoracic CT reporting. In each period, firstly, radiologists separately and blindly analyzed the 3 mm-thick images of the cases, and evaluated the number, localization and size of the nodules. For nodule size measurement, the largest diameter in the transverse plane was evaluated and analyzed by dividing into two groups as 4-5 mm and 5-10 mm. Nodules were recorded as sizes on the

pre-prepared evaluation form. Then, the same procedure was performed for the MIP images of all patients. Histopathological confirmation of the nodules for diagnostic accuracy was not required. Images that were 3 mm-thick and obtained in routine thoracic CT evaluations in our center were first individually evaluated by both of the observers, and then joint evaluation was performed for different interpretations, and the gold standard for the study was established.

MIP images and 3 mm-thick sections, which were set as the gold standard, were compared and sensitivity and positive predictive value (PPV) were calculated. Since there weren't any true negative patients, specificity and negative predictive value could not be calculated.

Statistical Analysis

Statistical analyses were performed with Statistical Package for Social Sciences (SPSS), 17.0 (IBM, SPSS Corp.; Armonk, NY, USA).

Among the groups, whether there was concordance between the MIP technique and the gold standard and between the observers was evaluated using "Intraclass correlation coefficient". For intraobserver concordance, a value below 0.20 was accepted as very poor concordance, between 0.21-0.40 as poor concordance, between 0.41-0.60 as moderate concordance, between 0.61-0.80 as high concordance, and between 0.81-1 as perfect concordance.

To evaluate whether there was a significant difference between the groups in terms of the duration of evaluation, "Paired Sample T-Test" was used. $p < 0.05$ was considered statistiscally significant.

RESULTS

In the separate and joint evaluations by both radiologists of the 3 mm-thick sections of 69 patients included in the evaluation, a total of 339 nodules were detected. Of these nodules, 152 (45%) had a diameter smaller than 5 mm, and 187 (55%) between 5-10 mm (Figure 1-4).

In the evaluations of the MIP images of detected nodules, the first observer detected 276 of 339 nodules (81.4%) by looking at the MIP images alone. Of these nodules, 116 (76.3%) had a diameter less than 5 mm, 160 (85.5%) between 5-10 mm. When this observation was compared with the gold standard, it was found that 19 of the nodules in the group with a
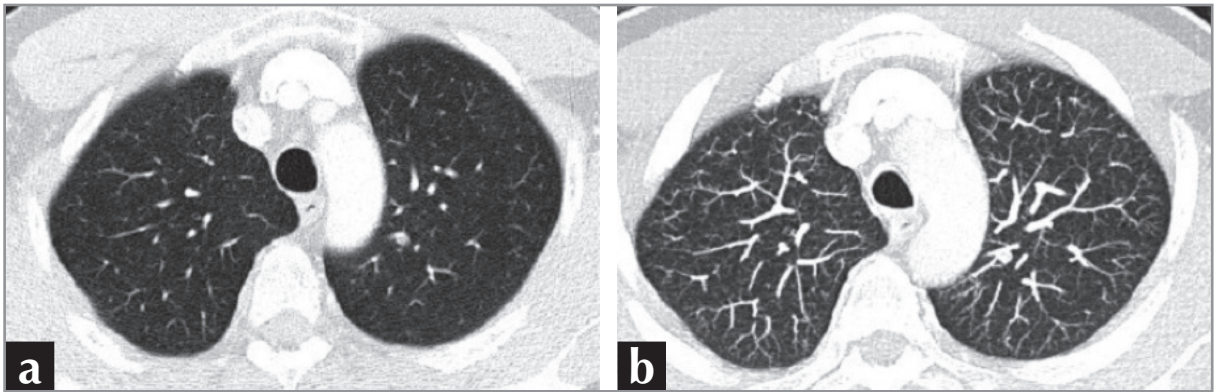
Figure 1. a. 47-year-old male patient. In figure 1a shows a nodule in the apical segment of upper lobe of the right lung in a 3-mm axial section. In figure 1b, the nodule in the upper lobe of the right lung is more clearly seen in axial MIP sections, apart from the vascular structures.
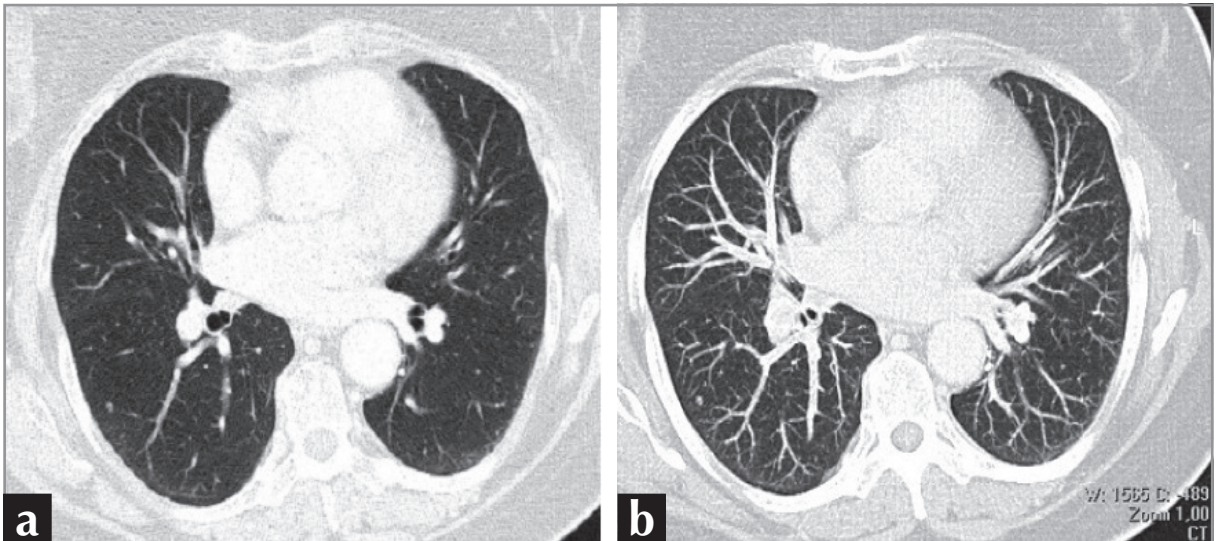

Figure 2. A 67-year-old female patient. In figure 2a, in 3 mm axial sections, the nodule is seen in the lower lobe of right lung. In figure 2b, in the axial MIP sections, the nodule in the lower lobe of the right lung is more clearly observed and detected by both observers.
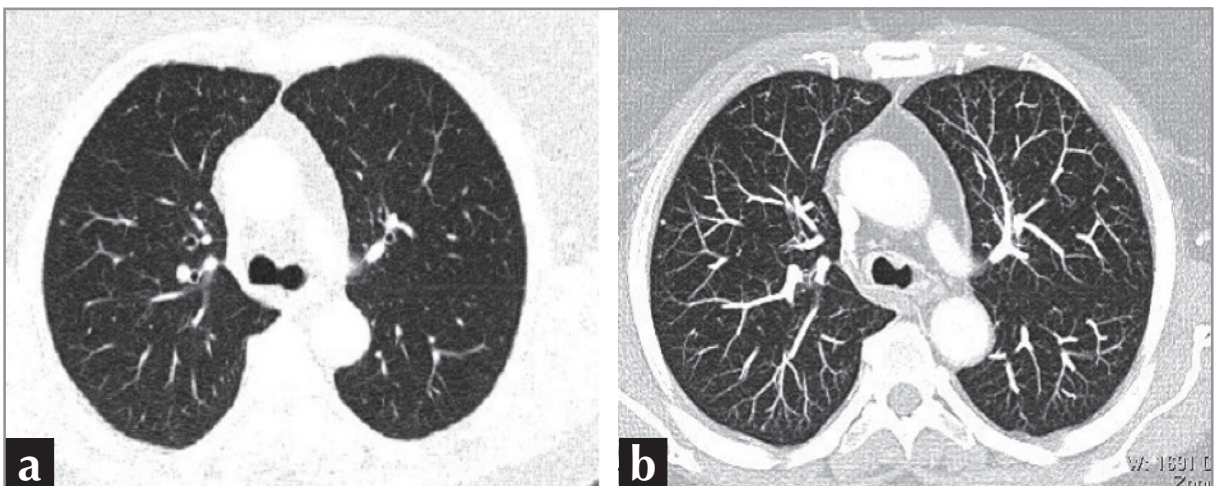

Figure 3. A 64-year-old female patient. Figure 3a shows a peripheral nodule in the right lung in axial 3 mm sections. In figure 3b, axial MIP sections show a more accurate nodule in the periphery of the right lung.
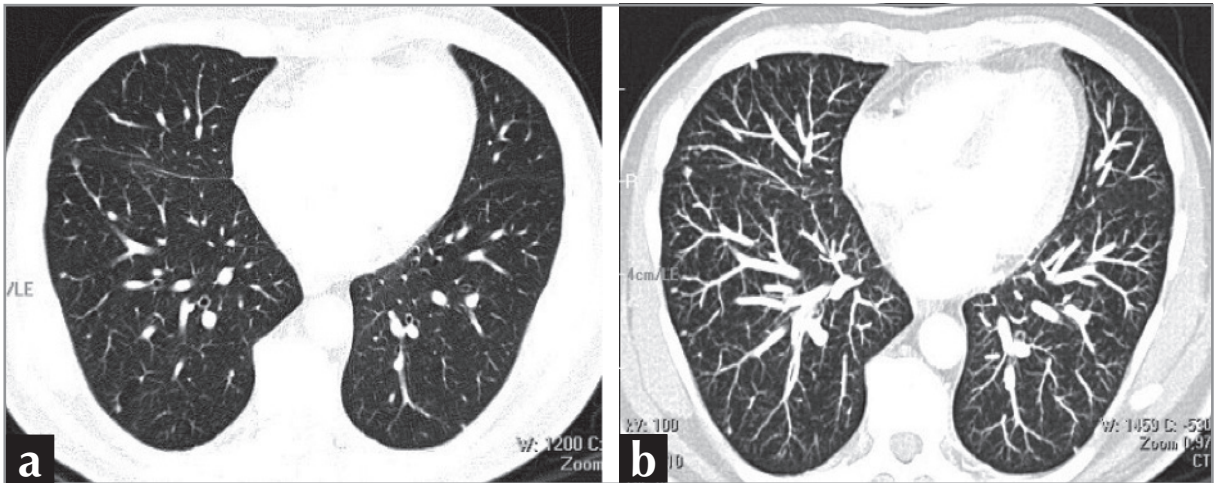
Figure 4. A 61-year-old male patient has multiple nodules on the right lung in figure 4a. In figure 4b, the nodules are more densely and clearly observed.

diameter less than 5 mm and 9 of the nodules in the group with a diameter between 5-10 mm were not actual nodules. These were recorded as false positives (Table 1).

In the evaluation of MIP images of detected nodules, the second observer detected 283 of the 339 nodules (83.4%). Of these nodules, 125 (82.2%) had a diameter smaller than 5 mm, and 158 (84.4%) between 5-10 mm. Similar to the previous evaluation, upon comparison with the gold standard, 12 nodules with a diameter less than 5 mm and 13 nodules with a diameter between 5-10 mm were not actual nodules. These were recorded as false positives of the second observer (Table 2).

Table 1. Sensitivity and PPV of the MIP for the first observer in nodule detection

	1. Observer MIP < 5 mm	1. Observer MIP 5-10 mm	1. Observer MIP Total nodules
True positive	116	160	276
False negative	36	27	63
False positive	19	9	28
Total	135	169	304
Sensitivity (%) (95% Confidence Interval)	76.3 (68.6-82.6)	85.5 (79.5-90.1)	81.4 (76.7-85.3)
PPV (%)	85.9	94.6	90.7

PPV: Positive predictive value, MIP: Maximum intensity projection.

Table 2. Sensitivity and PPV of the MIP for the second observer in nodule detection

	2. Observer MIP < 5 mm	2. Observer MIP 5-10 mm	2. Observer MIP Total nodules
True positive	125	158	283
False negative	27	29	56
False positive	12	13	25
Total	137	171	308
Sensitivity (%) (95% Confidence Interval)	82.2 (75-87.7)	84.4 (78.3-89.2)	83.4 (78.9-87.2)
PPV (%)	91.2	92.3	91.8

PPV: Positive predictive value, MIP: Maximum intensity projection.

Table 3. Average evaluation times of observers	
	Average ± Standard deviation
Time gold standard-1. observer	1.87 ± 0.56
Time MIP-1. observer	1.23 ± 0.22
Time gold standard 2. observer	2.25 ± 0.91
Time MIP-2. observer	1.69 ± 0.61
MIP: Maximum intensity projection.	

Table 4. p values of data compared to time	
	p
Time gold standard/MIP 1. observer	0.000*
Time gold standard/MIP 2. observer	0.000*
Time MIP 1/2. observer	0.000*
MIP: Maximum intensity projection. * p< 0.01.	

In the second stage of the evaluations, gold standard and the MIP evaluation durations of the observers were compared and whether there was a significant change in the duration of MIP evaluations were investigated. In both groups, evaluation durations of both observers were compared using Paired Sample T-Test. For the first observer, the mean duration of evaluation of the 3 mm-thick sections was 1.87 ± 0.56 minutes, and the mean duration of evaluation of the MIP images was 1.23 ± 0.22 minutes. For the second observer, the mean duration of evaluation of the 3 mm-thick sections was 2.25 ± 0.91 minutes, and the mean duration of evaluation of the MIP images was 1.69 ± 0.61 minutes. The statistical analysis has shown that both observers have evaluated the MIP images in a significantly shorter time (p< 0.05). Moreover, when the duration of evaluation of MIP images of the two observers were compared, the difference was found to be statistically significant (Table 3 and 4). It was concluded that this result is related to the difference in sensitivity in the detection of nodules with a diameter less than 5 mm.

DISCUSSION

The most important advantage of MIP imaging is that it increases noticeability as it accentuates the formations with high density and shows them as more hyperdense than the surrounding structure. With this property, vascular structures filled with contrasting agents, pulmonary nodules, calcifications and for-

eign substances can be more clearly and dramatically detected during the analysis of images. In this context, it saves the time spent and labour loss in the course of reporting (5).

In the recent studies on the sensitivity in the detection of pulmonary nodules using MIP imaging, very high sensitivity values were found. In the study by Grudent et al. (4), MIP images were compared with 3 mm-thick axial sections and it was shown that MIP evaluation detects the nodules within a shorter time and is more sensitive in nodule detection compared with axial sections.

In the study by Jankowski et al. (6), MIP images were compared with 1 mm-thick axial images and no significant difference was detected between the two modalities in terms of nodule detection, but it was concluded that MIP images are evaluated within a shorter time.

Valencia et al. (7) have compared 1 mm and 5 mm-thick CT sections with MIP imaging and found that the sensitivity in MIP evaluation is higher than the CT evaluation using both sections. In the study by Coakley et al. (8) on CT imaging on animals, 5 mm-thick sections were compared with MIP images and it was found that the detection rate of pulmonary nodules increases by 2.18% with MIP imaging. In the study by Kilburn et al. (9) on MIP imaging, pulmonary nodules in pediatric patients were evaluated using MIP imaging and 2 mm-thick axial sec-

tions. In the said study, joint evaluation of 2 mm-thick sections was accepted as the gold standard, MIP and 2 mm-thick sections were evaluated at different times and it was emphasized that the sensitivity of MIP images were much higher. Similar to our study, this study has also found that there can be more false positive values in MIP imaging.

Moreover, in the study by Gruden et al. (4), a patient's 3 mm-thick axial section was evaluated first, immediately followed by the patient's MIP section, and additional nodules detected in MIP were recorded. In our study, axial 3 mm-thick sections and MIP sections were evaluated separately at different times as it was considered it would be more accurate in detecting the sensitivity of the study, which lead to the generation of false negative results.

An overall assessment of all these studies reveals that the sensitivity of MIP imaging in detecting pulmonary nodules is superior to the CT evaluations performed using 5 mm-thick sections. However, in basic sectional evaluation, the inevitable increase in nodule detection sensitivity as the section thickness decreases is observed in almost all of the studies.

In this study which is conducted based on the gold standard images, the mean sensitivity of MIP imaging was found to be 82.4%. MIP imaging sensitivity values in other studies performed on this subject are similar to our study, and are between 77.5% and 86%.

In this study, PPV of MIP imaging recorded by both observers were close in nodules between 5-10 mm, whereas it was higher than the nodules smaller than 5 mm (for both observers, 94.6-92.3 vs. 85.9-91.2). This result was attributed to the fact that detection with CT criteria gets easier as the nodule size increases and false positive values are smaller in nodules between 5-10 mm.

When MIP imaging is evaluated in terms of duration, in the study by Gruden et al. (4), 3 minutes were assigned to axial images and 1 minute for MIP images that were in time limitation when axial and MIP images were evaluated, and nodules detected within this period were included in the evaluation, and it was found that the sensitivity of MIP evaluation was higher. In the study by Kilburn et al. (9), there were no time limitations when evaluating axial and MIP images and recorded the evaluation durations as they have done in this study.

In this study, there were no time limitations during the evaluation when analyzing axial and MIP images. The reason behind this is not only to investigate the sensitivity of MIP in nodule evaluation but also to identify its contribution to evaluation durations. Both observers have evaluated MIP images in a statistically significantly shorter time than 3 mm-thick axial images. Moreover, it was found that the first observer evaluated MIP images in a relatively shorter time than the 2nd observer. Consequently, it was found that the sensitivity of the 2nd observer, who performed MIP evaluation in a relatively longer time, in detecting the nodules smaller than 5 mm is higher than the 1st observer.

The greatest limitation of the study is that the false positive evaluations in MIP imaging in this study are relatively high in number. This outcome, which was observed in almost all studies in this subject, was also detected in this study. The most important cause of false positive results in this study is the exclusion of nodules between 3-4 mm from the study.

MIP imaging shows pulmonary nodules as more dense, MIP evaluation of nodules between 3-4 mm that were excluded from the study causes their diameters to be measured larger, and false positive nodules can be observed particularly when subpleural sequela changes are visualized with MIP imaging. Consequently, nodules that were actually nodules but were excluded from the study because of their diameter and subpleural sequela changes caused the false positivity to increase particularly in nodules smaller than 5 mm. In the study by Gruden et al. (4), nodules between 3-9 mm were included in the study, and excluded nodules smaller than 3 mm as they can affect the sensitivity of the study and set no limitations regarding the nodule size included in the study.

Another limitation of our study was that the interval for nodule diameter in both groups (4-5 mm and 5-10 mm) was high. The nodule diameter interval in the first group (4-5 mm) was 1 mm whereas it was 5 mm in the second group (5-10 mm). The reason behind this grouping by the observers was the higher number of nodules that were smaller than 5 mm and that a follow up was not recommended by the basic protocols such as Fleschner classification for the nodules smaller than 4 mm other than high-risk patients.

The final limitation of the study is the lack of definitive histopathological diagnosis of the nodules. In routine clinical practice, histopathological confirmation is not done unless there is an increase in the size of pulmonary nodules, and follow-up with CT at regular intervals is recommended. In the similar studies in literature, axial sections or the highest number of nodules detected by the observers are accepted as the gold standard due to these reasons (4,9). In our study, the gold standard was established by the joint decision of both observers as 3 mm-thick axial sections.

In our study, it was shown that evaluation of nodules between 4-10 mm by MIP imaging enables the nodules to be detected with high sensitivity and in a significantly shorter time. Thus, MIP imaging can be recommended in the evaluation of nodules between 4-10 mm. However, considering the limitations of our study, it should be considered as an auxiliary and complementary modality that must be used alongside axial thin sections in nodule evaluation rather than being used alone.

CONFLICT of INTEREST

There is no conflict of interest related to this study.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: KH

Analysis/Interpretation: MC, KH

Data Acquisition: PGK

Writting: PGK

Critical Revision: ŞA

Final Approval: KH

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