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The role of endobronchial ultrasonography elastography for predicting malignancy

Endobronşiyal ultrasonografi elastografinin maligniteyi öngörmedeki rolü

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ABSTRACT

Background: This study aims to investigate the role of endobronchial ultrasonography elastography in predicting malignancy.

Methods: Between January 2016 and December 2016, a total of 221 lymph nodes were biopsied using the endobronchial ultrasonography-guided transbronchial needle aspiration from 119 consecutive patients (69 males, 50 females; mean age 63.2±12.4 years; range, 16 to 86 years) were included. Lymph nodes were scored by elastography according to their colors in four categories before the procedure. The strain ratio was calculated based on the region of interest after three measurements.

Results: Of the patients, 93 were diagnosed with a malignancy through endobronchial ultrasonography-guided transbronchial needle aspiration biopsy. The mean lymph node score of benign versus malignant lesions was 2.2±1.0 and 3.2±1, respectively ($p<0.001$). There was a positive correlation between the lymph node scores and lymph node diameter, strain ratio, and fluorodeoxyglucose uptake value ($p<0.01$). With a cut-off value of ≥3 of lymph node scoring, the sensitivity for malignancy was 79% and specificity was 60%. The mean strain ratio for malignant and benign lymph nodes was 22.2±30.1 and 5.2±1.7, respectively ($p<0.001$). With a cut-off value of ≥2.47 of strain ratio, the sensitivity for malignancy was 75% and specificity was 65%. The combined use of positron emission tomography and lymph node score or strain ratio yielded 80.4% and 61.2% sensitivity and 80% and 70.3% specificity for malignancy, respectively.

Conclusion: Endobronchial ultrasonography elastography is useful in predicting malignancy of the lymph nodes. When combined with positron emission tomography, specificity and positive predictive value for malignancy increase.

Keywords: Bronchoscopy, endobronchial ultrasonography, lung cancer, lymphadenopathy, transbronchial needle aspiration biopsy.

ÖZ

Amaç: Bu çalışmada endobronşiyal ultrasonografi elastografinin maligniteyi öngörmedeki rolü araştırıldı.

Çalışma planı: Ocak 2016 - Aralık 2016 tarihleri arasında, endobronşiyal ultrasonografi eşliğinde transbronşiyal iğne aspirasyon biyopsisi ile 119 ardışık hastadan (69 erkek, 50 kadın; ort. yaş 63.2±12.4 yıl; dağılım 16-86 yıl) toplam 221 lenf nodu çalışmaya alındı. Lenf nodları işlem öncesinde elastografi ile renklerine göre dört kategoride skorlandı. Gerginlik oranı, üç ölçüm sonrasında ilgili bölgeye göre hesaplandı.

Bulgular: Hastaların 93'üne endobronşiyal ultrasonografi eşliğinde transbronşiyal iğne aspirasyon biyopsisi ile malignite tanısı konuldu. Benign ve malign lenf nodlarının ortalama skoru sırası ile 2.2±1.0 ve 3.2±1 idi ($p<0.001$). Lenf nodunun skoru ve lenf nodunun çapı, gerginlik oranı ve florodeoksiglukoz alım değeri arasında pozitif bir ilişki vardı ($p<0.01$). Lenf nodu skorunun ≥3'lük eşik değeri ile malignite için duyarlılık %79 ve özgüllük %60 idi. Malign ve benign lenf nodlarının ortalama gerginlik oranı sırası ile 22.2±30.1 ve 5.2±1.7 idi ($p<0.001$). Gerginlik oranının ≥2.47'lik eşik değeri ile malignite duyarlılığı %75 ve özgüllüğü %65 idi. Pozitron emisyon tomografisi ve lenf nodu skoru veya gerginlik oranı birlikte kullanıldığında, malignite duyarlılığı sırası ile %80.4 ve %61.2 ve özgüllüğü %80 ve %70.3 idi.

Sonuç: Endobronşiyal ultrasonografi elastografi, lenf nodu malignitelerini öngörmede yararlıdır. Pozitron emisyon tomografisi ile birlikte kullanıldığında, malignite özgüllüğü ve pozitif öngördürücü değeri artar.

Anahtar sözcükler: Bronkoskopi, endobronşiyal ultrasonografi, akciğer kanseri, lenfadenopati, transbronşiyal iğne aspirasyon biyopsisi.

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Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) is the most common method in mediastinal staging of non-small cell lung cancer (NSCLC) and in the diagnosis of hilar and mediastinal lymphadenopathies in the last decade. Positron emission tomography (PET), which is recommended for staging of NSCLC by the guidelines, has a high sensitivity for the malignant lymph nodes (LNs), but has low specificity. Granulomatous diseases such as tuberculosis, sarcoidosis, and non-specific infections falsely raise the fluorodeoxyglucose (FDG) activity of the LNs. Additional diagnostic tests are required for the LNs with a high FDG activity and this confirmation can be achieved with proper tissue analysis.[1,2]

Until now, clinical studies and meta-analysis have proved EBUS-TBNA as being a highly sensitive, specific, safe, and minimally invasive method for the diagnosis of malignant LNs. In the light of these data, EBUS has found a place as the first-line tool for the tissue diagnosis in mediastinal staging of lung cancer in many guidelines.[1,3-6]

The ability of the bronchoscopist to predict malignancy from a large number of LNs detected during EBUS shortens the duration of the procedure and increases the patient's tolerance to intervention.[6,7] The sonographic evaluation of the nodes according to some morphological characteristics such as size, echogenicity, and margin specifications have been found useful in identifying nodal metastasis.[7] However, it is not easy for certain cases to predict malignancy using only morphological characteristics with B-mode ultrasonography.

Elastography is a novel ultrasonographic technique which detects the elasticity or the resistance of the tissue to deformation. It was first used in 1991 for the differential diagnosis of breast and later pancreatic lesions and was found to have a high sensitivity for malignancy.[8,9] Malignant tissues, due to their high vascularity and cellularity, are less deformable or stiff which allow them to be recognized by elastography. The stiffness of the pathological tissue is determined by the deformity caused by the mechanical or vibrational forces. Elastography assesses the tissue stiffness and visualizes the distribution of stiffness in the region of interest (ROI). The feedback on tissue stiffness is converted into a color-coded image and displayed in color on an ultrasound image to predict malignancy (color score [CS]). Regardless of the scoring method, the lowest CS represents the softest lesion and the highest score represents the hardest lesion.[8-16] During elastography, the strain ratio (SR) is measured, which is the ratio (B/A) between the average elasticity of the lesion (A) and the normal tissue (B), and calculated by software of the device. The general principle is that the A zone should cover the entire lesion area as much as possible.[10]

Trosini-Désert et al.[17] has shown that elastography can possibly improve the diagnostic yield of EBUS and that tracheobronchial cartilage does not appear to interfere with the collection of this type of information. Further studies have also confirmed these findings. With the integration of the elastography into the EBUS, several studies have shown the ability of this method in detecting malignant LNs with high sensitivity and acceptable specificity. Pulsatile properties of the aorta and heart cause an intermittent pressure on the adjacent tissues and LNs, and elastographic imaging of the mediastinal LNs can be taken by EBUS elastography.[3,10,11,14,15]

In the present study, we aimed to investigate the role of EBUS elastography in predicting the results of EBUS-TBNA, to examine the relationship between the LN morphology and FDG uptake, and to identify the contribution of elastography to the sensitivity and specificity of PET.

PATIENTS AND METHODS

This single-center, prospective study was conducted at Koç University School of Medicine between January 2016 and December 2016. A total of 221 lymph nodes were biopsied using the endobronchial EBUS-TBNA for diagnostic and/or staging from 119 consecutive patients (69 males, 50 females; mean age 63.2±12.4 years; range, 16 to 86 years) were included. All patients were examined using chest X-ray, thoracic computed tomography (CT), and PET, if indicated. Data including complete blood count, prothrombin time before the EBUS, electrocardiography, and other biochemical analysis results were recorded. The LNs with a short axis of ≥1 cm and/or with a FDG uptake of ≥2.5 on PET were accepted as pathological and sampled. In staging, LNs of ≥0.5 cm were sampled, irrespective of the FDG activity. A written informed consent was obtained from each patient. The study protocol was approved by the Ethics Committee of Koç University School of Medicine (No. IRB1.003). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The EBUS-TBNA was performed via oral route with conscious or deep sedation/local anesthesia or under general anesthesia via endotracheal tube according to the patient or physician preference. Midazolam and/or fentanyl and/or propofol were used

for sedation. All EBUS and elastography measurements were made by the same two chest physicians. The Convex probe-EBUS (BF-UC180F; Olympus Ltd., Tokyo, Japan) equipped with a linear probe on its tip was used to perform EBUS-TBNA. The ultrasound image was processed with a universal endoscopic ultrasound scanner (EU-ME2 Premier Plus, Olympus Ltd., Tokyo, Japan) at a frequency of 10 MHz. The LN stations were defined according to the eighth edition of the Tumor, Node, Metastasis staging system.[18] The location of the station, short axis diameter, margin characteristics, shape, echogenicity, heterogeneity, and number of aspirations were recorded during the B-mode ultrasonography. Elastography was performed after B-mode ultrasonography. The adjacent normal tissue was included in the area visualized with the LN. B-mode ultrasonography images and elastography images were simultaneously displayed on the screen side by side. The stiffness of the tissue was determined by the operator according to the CS. Blue represented the hardest, and red represented the softest tissue, respectively. In our study, the following grading system was used: 1 point when over 80% of the section was green and yellow/red; 2 points when over 50% but <80% of the section was green and yellow/red; 3 points when over 50% but <80% of the section was blue; and 4 points when over 80% of the section was blue.[3]

For the SR measurement, the largest possible area of the LN and the adjacent normal tissue were included in the ROI and LN, and normal tissue were marked with the same size for measuring A and B. The SR (B/A) was calculated using a software. The SR was not measured in the presence of normal tissue containing vascular or aerated structures. The mean value of three consecutive measurements of SR with the same reference tissue was calculated as the SR. After recording the results of CS and SR, EBUS-TBNA was performed using an Olympus ViziShot NA-SX 22-gauge needle, and histological and cytological specimens were collected for the analysis by the pathologists. Rapid on-site evaluation (ROSE) was available during all procedures and pathologists were blinded to the CS and SR results. The aspiration was terminated after adequate specimens were obtained for the diagnosis according to the ROSE. The relationship between the EBUS-derived pathological results, FDG uptake value, elastography score, and SR was evaluated. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of EBUS elastography for malignancy were calculated for the single and combined use of PET, SR, and CS methods. In addition, the relationship between the CS, SR and LN morphology and FDG uptake value of LN and the relationship between the CS and SR were examined. Only LNs with adequate lymphocytes or those with a definitive diagnosis were included in the analysis. The pathological results of EBUS-TBNA were considered as the gold standard in this study.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were expressed in number and frequency. The comparison of categorical variables was performed using the chi-square and Fisher's exact tests. The Shapiro-Wilk test was used to identify whether the continuous variables were normally distributed. For continuous variables, the Student's t test and Mann-Whitney U test were used relative to the normality of distribution of the variables. The Spearman's correlation test was used to analyze the relationship between continuous variables. The cut-off value for the discrimination of benign/malignant based on elastography CS and SR was calculated by the Receiver Operating Characteristic (ROC) curve. A p value of <0.05 was considered statistically significant.

RESULTS

Conscious and deep sedation were used in 65 patients, while 54 patients were intubated under general anesthesia according to the patient and operator preferences. The purpose of EBUS was initial diagnosis in 70, diagnosis and staging of lung cancer in 34 patients, staging of lung cancer in eight, re-staging in one, and suspected relapse in six patients. Histological and cytological results confirmed 93 malignant cases by EBUS, 80 among them being primary lung cancer. Seventeen patients were diagnosed with granulomatous disease and nine with reactive-anthracotic lymphadenitis. Among the LNs, 4R was the most commonly sampled with a ratio of 33.4%, followed by No 7 and 4L (Figure 1). In our study, a mean of 2±1 (1-5) LN stations were sampled per patient and a mean of 3.4±1.4 (1-9) passes were obtained from each station. The mean short axis diameter of the sampled nodes was calculated as 16.2±11.1 (range, 3 to 80) mm.

Based on morphological features, 89.6% of the LNs had distinct margins, 45.2% had heterogeneous echogenicity, 46.2% were hypoechoic, 0.5% hyperechoic, and 8.1% had isoechoic pattern. In addition, 84.2% of the LNs were round-shaped and the remaining were oval or triangle.

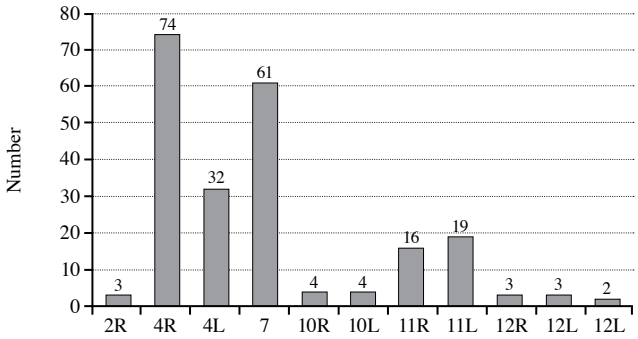

Figure 1. Distribution of the lymph node stations.

In our study, the elastographic patterns and FDG activity of LNs were compared with the final pathological results from EBUS-TBNA. Elastographic CS of 206 LNs was calculated and among them 114 were found to be benign and 92 malignant in nature. The score was 1 in 24.3%, 2 in 17.9%, 3 in 27.6%, and 4 in 30.2% of the lesions. One LN which was regarded as inadequately sampled and one LN where atypical cells were reported were excluded. Thirteen LNs were unable to be scored properly due to technical problems. The mean elastography CS for benign and malignant results was 2.2±1.0 and 3.2±0.9, respectively, indicating a statistically significant difference (p<0.001). There was a positive correlation between the CS and LN diameter, SR, and FDG uptake (p=0.001, p<0.001, p=0.003, respectively). We calculated a cut-off value for the discrimination of benign versus malignant results from 206 LNs where CS could be calculated. When the cut-off value was set to be ≥3, the ROC analysis (area under the curve [AUC]= 0.728, p=0.001) revealed 79% sensitivity, 60% specificity, 61% PPV, 78% NPV, and 68% accuracy (Figure 2).

The SR was measured in 195 LNs in our study. The mean SR of malignant lesions (n=85) was significantly higher (22.2±30.1) than that of their benign counterparts (n=110) (5.2±1.7) (p<0.001). A positive correlation between the SR and lesion diameter (p<0.001) and FDG uptake (p=0.02) was detected. The ROC analysis for SR when the cut-off was set to ≥2.47 for malignancy revealed (AUC=0.750 p<0.001) 75% sensitivity, 65% specificity, 62% PPV, 77% NPV, and 69% accuracy (Figure 3). Table 1 displays the CS and SR values according to different diagnostic groups. The SR was significantly higher in breast cancer cases compared to other malignant cases; however, due to low small sample size, we were unable to make an accurate evaluation.

The sensitivity of PET (FDG uptake ≥2.5) in predicting malignant result of EBUS-TBNA was found to be 98.2% with 20.8% specificity, 49.6% PPV, 93.8% NPV, and accuracy 55%. On the other hand, when an elastography CS of ≥3 and FDG uptake of ≥2.5 were combined for predicting malignancy, the values were

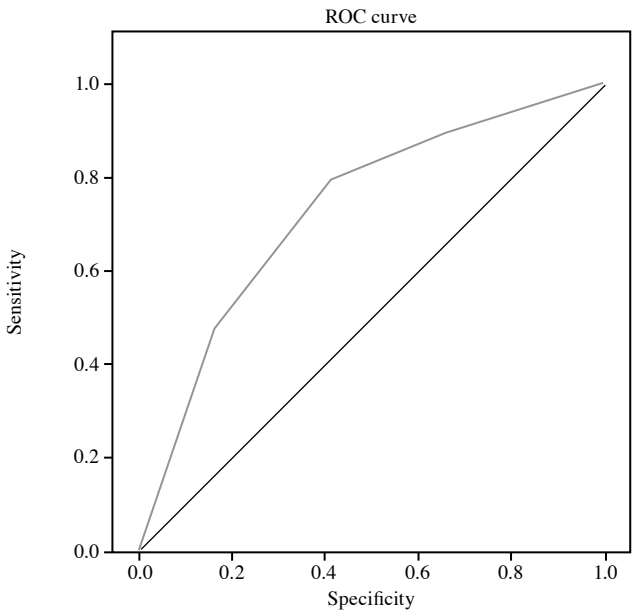

Figure 2. ROC analysis of the color score with a cut-off value of ≥3.
ROC: Receiver operating characteristic.

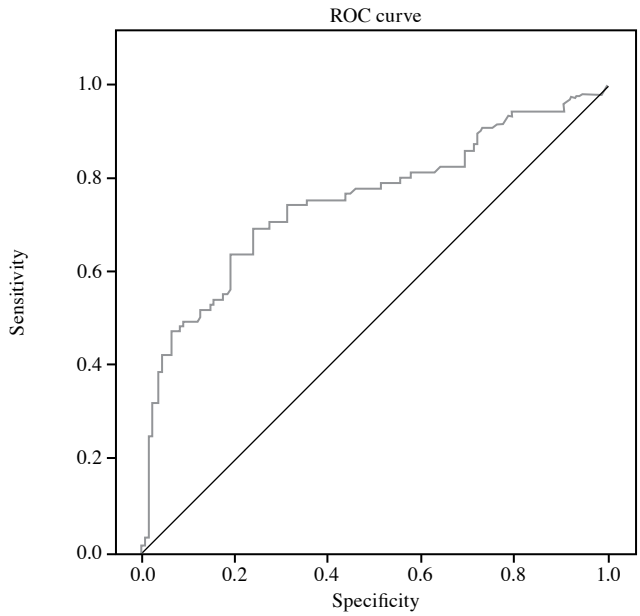

Figure 3. ROC analysis of the strain ratio with a cut-off value of ≥2.47 for malignancy.
ROC: Receiver operating characteristic.

Table 1. Final diagnosis and mean elastographic values of sampled lymph nodes

	n	Mean±SD	
Color score			
Lymphoid material	46	1.9±1.0	
Anthracotic LN	44	2.3±1.2	
Granuloma	24	2.5±1.1	
Small cell Ca	22	3.0±1.0	
Adeno Ca	33	3.4±0.9	
Squamous Ca	16	3.5±0.7	
NSCLC	11	3.1±0.9	
Lymphoma	4	1.5±1.0	
Breast Ca	4	4.0±0.0	
Seminoma	1		3.00
RCC	1		3.00
Total	206		
Strain ratio			
Lymphoid material	40	4.9 ±13.3	
Anthracotic LN	50	5.9±21.6	
Granuloma	20	4.0±7.8	
Small cell Ca	24	15.7±19.6	
Adeno Ca	27	22.6±39.6	
Squamous Ca	13	19.6±20.0	
NSCLC	12	27.5±29.6	
Lymphoma	4	2.6±4.3	
Breast Ca	4	70.3±35.2	
Seminoma	1		34.80
Total	195		

SD: Standard deviation, LN: Lymph node, Ca: Carcinoma; NSCLC: Non-small cell lung cancer, RCC: Renal cell carcinoma.

80.4%, 61.2%, 63,4%, 78.8%, and 69.9%, respectively. When a SR of ≥2.47 and FDG uptake of ≥2.5 were evaluated as alterative, these values were 80%, 70.3%, 67.8%, 81.8%, and 74.6%, respectively (Table 2). These findings showed a positive correlation between the standardized uptake value (SUV) of the LN and CS and SR ($p<0.05$).

DISCUSSION

The sonographic features of the LNs during EBUS-TBNA are helpful in predicting malignancy. Fujiwara et al.[7] reported that round shape, distinct margin, heterogeneous echogenicity, and presence of coagulation necrosis sign were independent predictive factors for metastasis. As these features alone do not carry high sensitivity and specificity, new markers are still needed. In our study where we investigated the value of EBUS elastography in predicting malignant results of EBUS-TBNA, we found that CS and SR were significantly higher in malignant LNs compared to their benign counterparts ([2.2±1.0 vs. 3.2±0.9 and 22.2±30.1 vs. 5.2±1.7, respectively ($p<0.001$]). The ROC analysis for SR when the cut-off was set to ≥2.47 for malignancy revealed (AUC=0.750 $p<0.001$) 75% sensitivity, 65% specificity, 62% PPV, 77% NPV, and 69% accuracy. On the other hand, for the CS, when the cutoff value was set to be ≥3, the ROC analysis (AUC=0.728, $p=0.001$) revealed 79% sensitivity, 60% specificity, 61% PPV, 78% NPV, and 68% accuracy. In our study, there was a positive correlation between the CS/SR and LN diameter and FDG uptake. When a FDG uptake value of ≥2.5 was combined with either CS or SR, it yielded an increase in the sensitivity, specificity, PPV, and NPV for malignancy compared to CS or SR alone. When the SR and CS were combined with PET, NPV and sensitivity decreased compared to PET alone. On the other hand, higher PPV and specificity values were achieved with this combination. The accuracy of PET increased from 55 to 74.6%, when SR+PET were used in combined. The CS combined with PET had an accuracy of 69.9%.

To the best of our knowledge, there is only one study in the literature investigating transthoracic ultrasound elastography in thoracic lesions.[19] In this study, Sperandeo et al.[19] concluded that malignant lesions had greater stiffness compared to benign ones, and the elasticity of squamous cell carcinoma (SCC) was significantly lower than any other type of

Table 2. Values of FDG uptake and FDG uptake-strain ratio or color score combination in predicting malignancy

	Sensitivity	Specificity	PPV	NPV	Accuracy
	%	%	%	%	%
SR ≥2.47	75	65	62	77	69
CS ≥3	79	60	61	78	68
FDG ≥2.5	98.2	20.8	49.6	93.8	55
FDG ≥2.5 + CS ≥3	80.4	61.2	63.4	78.8	69.9
FDG ≥2.5 + SR ≥2.47	80	70.3	67.8	81.8	74.6

FDG: Fluorodeoxyglucose, PPV: Positive predictive value, NPV: Negative predictive value, SR: Strain ratio, CS: Color score.

cancer. In another study on EBUS elastography, tissue elasticity was found to be lower; namely the CS was higher in SCC cases.[15] Similarly, we found higher CS in SCC cases consistent with these studies.

The review of the literature on EBUS elastography reveals that using elastographic parameters such as CS and/or SR may be helpful in predicting malignancy.[3,11,14-16,20-22] Nakajima et al.[14] evaluated EBUS elastography compared to EBUS-TBNA results. In their retrospective study, 49 hilar and mediastinal LNs and calculated the blue area in the ROI (SAR: stiff area ratio). They found out that the mean SAR was significantly higher for metastatic LNs than for benign nodes. In this study, sensitivity and specificity of elastography were found to be 81% and 85% respectively. In another series, the sensitivity, specificity, and accuracy were calculated as 92.3%, 67.5%, and 78.5%, respectively, when the blue color proportion cut-off was set as 36.7%.[15] In the study of Izumo et al.,[11] in cases which were classified as predominantly blue (type 3), the sensitivity for malignancy was 100% with 96.7% accuracy. Similarly, in another series, benign LNs were classified as type 1 (predominantly non-blue) and malignant nodes as type 3 (predominantly blue), and the sensitivity, specificity, PPV, NPV, and diagnostic accuracy were as follows: 96.4%, 86.7%, 87.1%, 96.3%, and 91.4%, respectively.[16] In another retrospective series using the same criteria, the sensitivity, specificity, PPV, NPV, and accuracy were 90.6%, 82.6%, 71.6%, 94.7%, and 85.2%, respectively.[23] The results of these studies were calculated according to the pathological examinations of the EBUS-TBNA samples. In both studies, type 2 LNs comprised the intermediate class, which makes the prediction more difficult. However, once adequate material is achieved in the benign pole of the spectrum, the operator may finish sampling. On the contrary, in the malignant pole, namely predominantly blue LN, more aspirations are needed for the accurate diagnosis. In another study, a total of 57 patients with central lung lesions underwent EBUS elastography and with a cut-off value for elastography grading score of 2.5 (AUC=0.793), the sensitivity, specificity, PPV, NPV, and accuracy were found to be 72.2%, 76.2%, 83.4%, 61.5%, and 73.7%, respectively.[20]

The SR is the another elastographic method which can be used to predict malignancy by quantitative analysis of the tissue stiffness. Rozman et al.[21] designed the first prospective study to investigate the role of elastographic SR in mediastinal staging of NSCLC. The mean SR was 19.0±18.3 and 6.3±7.3 in malignant and benign LNs, respectively. At a SR of ≥8, the accuracy for malignancy prediction was 86.2% (sensitivity 88.2%, specificity 84.7%, NPV 90.7%). There was no significant correlation between the LN diameter and SR, when benign and malignant LNs were evaluated separately. Later studies about this topic also support the findings of Rozman et al.[21] In the study of He et al.[3] where 40 patients were included, the best cut-off value of the SR for differentiating malignant from benign LNs was calculated as 32.07. The elastography SR had a sensitivity of 88.1% and specificity of 80.8%. Additionally, the SR and CS were found to be correlated. In another prospective study, where the cut-off value for SR was set as ≥5, 100% sensitivity, 70.8% specificity, 93.2% PPV, and 100% NPV were reported.[24] Consistent with the aforementioned studies, we found significantly higher SR in malignant LNs compared to benign ones. Our cut-off value between malignant versus benign lesions was lower than the one of Rozman[21] and Hai,[3] but similar to the one of Korrungrad.[24] Of note, our study differed from the one of Rozman et al.[21] in that the diameter of the LN was found to be correlated with the SR and CS.

It has been well established that sonographic findings such as size, echogenicity, and margins are critical determinants of nodal metastasis in NSCLC. The sensitivity of morphological characteristics including size, margin, and echogenicity was found to be 70% in the study of Izumo et al.[11] Literature studies regarding elastography revealed that parameters such as SR and CS proved to be more sensitive than these features in predicting malignancy.[3,11,15,20,21] In the study of Gu et al.[22] elastography, heterogeneity, size, and shape together were more successful than elastography alone in predicting malignancy. In our study, we were unable to calculate the sensitivity of every morphological feature, but only diameter of the LN was found to be correlated with the elastography results.

In their study, Ma et al.[15] reported the sensitivity and specificity of PET (SUV >2.5) in predicting LN metastasis as 100% and 15.4%, respectively. In 65.5% of predominantly blue LNs, SUV was >2.5, whereas only 34.6% of predominantly non-blue LNs had a SUV of >2.5. Verhoeven et al.[25] reported that combining EBUS-semiquantitative elastography with pre-test contrast-enhanced CT and FDG-PET avidity improved the predictive accuracy of LN pathology in both PET-CT negative and positive imaging cases. In this study, the relative stiffness of LNs, thus, seems to show an additional value to the metabolic and size data as given by FDG-PET and CT. In our study, the

results also showed a positive correlation between the SUV of the LN and CS and SR ($p<0.05$). The PET alone had a sensitivity of 98.2% and specificity of 20.8% in estimating malignancy. When combined with CS or SR, its sensitivity decreased, but the specificity increased to 61.2% and 70.3%, respectively.

The main limitations of the present study include its single-center and retrospective design. Apart from this, thirteen LNs were unable to be scored properly due to technical problems. We did not compare the final pathology results with the gold standard method, namely surgical biopsy. The SR was significantly higher in breast cancer cases compared to other malignant cases; however, due to low small sample size, we were unable to make an accurate evaluation.

In conclusion, our study results suggest that endobronchial ultrasonography elastography is useful in predicting malignancy of the lymph nodes. When combined with positron emission tomography, specificity and positive predictive value for malignancy increase. Therefore, particularly in staging cases with multiple lymph nodes in a single station, using elastography with B-mode ultrasonography may indicate which lymph nodes to prioritize. This may also shorten the duration of the bronchoscopy, if the Rapid on-site evaluation is available.

Declaration of conflicting interests

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