Original Article

Utility of Ultrasound Elastography to Differentiate Benign from Malignant Cervical Lymph Nodes

Vikrant Kanagaraju*, A. V. B. Rakshith, B. Devanand, R. Rajakumar
Department of Radiology, PSG Institute of Medical Sciences and Research, Coimbatore, Tamil Nadu, India

Abstract

Background: The purpose of this study was to evaluate the usefulness of strain elastography and acoustic radiation force impulse (ARFI) imaging in the differentiation of benign and malignant cervical lymph nodes (LNs). **Materials and Methods:** In this prospective study, 50 enlarged cervical LNs (33 benign and 17 malignant) were examined by B‑mode ultrasound (US), color Doppler, and strain elastography. Elastographic patterns (1–5) were categorized based on distribution of hard area within LN. The shear wave velocity (SWV) of LNs was evaluated by ARFI imaging. Diagnostic performance of sonoelastographic parameters was compared taking histopathology of LN as a reference standard. Optimal cutoff value of the mean SWV values for predicting malignancy was determined using receiver operating characteristic curve analysis. **Results:** Among US parameters, borders of LN had the highest diagnostic accuracy (80%), while echogenicity had the least (48%). Majority of benign LNs ($n = 31$) had elastography patterns 1 and 2, while majority of malignant LNs ($n = 16$) had patterns 3–5 ($P = 0.000$). The sensitivity, specificity, and accuracy of elastography were 94.1%, 93.9%, and 94%, respectively. The mean SWV of benign LNs (1.670 ± 0.367 m/s) differed significantly from malignant LNs (2.965 ± 0.826 m/s; $P = 0.000$). A cutoff value of 2.05 m/s predicted malignancy with 88.2% sensitivity and 84.8% specificity and gave an area under the curve of 0.949 (95% confidence interval: 0.70–1.20). **Conclusion:** Elastography has high diagnostic accuracy in differentiating benign and malignant cervical LNs and can be potentially useful in selecting the LN with high probability of malignancy, on which fine‑needle aspiration cytology/biopsy can be performed.

Keywords: Acoustic radiation force impulse imaging, elastography, lymph nodes, ultrasound

Introduction

Cervical lymphadenopathy, a common condition encountered by physicians in clinical practice, could be caused by a variety of pathologic processes such as infections, vasculitis, and malignancies such as lymphoma and metastases. Metastatic cervical lymphadenopathy is a common problem in head and neck oncology. Depending on the primary site, up to 80% of patients with upper aerodigestive mucosal malignancy have been reported to have cervical nodal metastasis at presentation.[1] The differentiation of malignant from benign lymph nodes (LNs) is essential because it predicts the patient prognosis and helps in decision‑making and planning of management.[2]

High‑resolution ultrasound (US) is the extensively used imaging technique for evaluating the morphology and internal architecture of cervical LNs. Color Doppler sonography is used to assess the pattern of intranodal vessels, blood flow velocity, and vascular resistance.[3] Although Gray‑scale sonography in combination with Doppler has been suggested to be useful in differentiating metastatic LNs from reactive ones based on various criteria, there is no single US criterion for diagnosing malignant LNs with satisfactory sensitivity and specificity.[4,5]

Real‑time elastography (RTE) is a novel, noninvasive imaging modality that assesses tissue elasticity by comparing local tissue displacement from US signals before and after the application of a compressive force.[6] Stiff tissues show less deformation (strain) than soft tissues under the compression of a transducer. Since malignant tissues are stiffer than their benign counterparts at many

Received: 13-07-2019 **Revised:** 26-07-2019 **Accepted:** 12-08-2019 **Available Online:** 10-12-2019

Access this article online
Quick Response Code:
Website: www.jmuonline.org
DOI: 10.4103/JMU.JMU_72_19

Address for correspondence: Dr. Vikrant Kanagaraju, Department of Radiology, PSG Institute of Medical Sciences and Research, Coimbatore - 641 004, Tamil Nadu, India. E-mail: vikrantmailin@gmail.com

How to cite this article: Kanagaraju V, Rakshith AV, Devanand B, Rajakumar R. Utility of ultrasound elastography to differentiate benign from malignant cervical lymph nodes. J Med Ultrasound 2020;28:92-8.

sites, several reports have documented the utility of US elastography in differentiating malignant from benign lesions in the breast, prostate, liver, thyroid, and cervix.[7-11] There are two types of elastography techniques, namely strain elastography and shear wave-based elastography. Recent studies have shown the usefulness of strain elastography in differential diagnosis of benign and malignant cervical LNs.[12-14] However, some authors have questioned its additional value over conventional US in predicting malignancy and decision-making in terms of selection of LNs for biopsy.[15-17] Shear wave elastography with acoustic radiation force impulse (ARFI) imaging is an emerging sonographic technique in the assessment of malignant cervical nodes.[18,19]

Data on the utility of elastography in the evaluation of cervical LNs are relatively few, especially from India. The purpose of the present study was to evaluate the utility and diagnostic performance of strain elastography compared to conventional B-mode US and color Doppler in the differentiation of benign and malignant cervical LNs. We also investigated the usefulness of ARFI imaging in differentiating benign and malignant LNs.

Materials and Methods

This prospective study was performed at a tertiary care center in South India between August 2016 and February 2018. Fifty LNs of 50 consecutive patients who were referred for ultrasonogram of enlarged cervical LNs were enrolled. The Institutional review board (IRB) approved the study protocol, and the protocol complied with the tenets of the Declaration of Helsinki (IRB Approval No. 16/334). Informed consent was obtained from all participants. Patients with suboptimal image quality and those with completely necrotic nodes without solid component were not included. Patients who had received specific treatment (chemotherapy/radiotherapy) were also excluded from the study.

High-resolution US imaging was performed in the supine position with a high-frequency linear probe 9 L4 (Siemens Accuson S3000, Siemens Healthineers, Erlangen, Germany) by a single expert radiologist, blinded to patient's clinical profile. In gray-scale US, the LNs were evaluated for short-axis diameter and short-to-long axis diameter ratio (S/L ratio) in the longitudinal plane, borders (regular or irregular), echogenicity (homogeneous/heterogeneous), and hilum (present or absent). Intranodal vascular pattern was evaluated using color Doppler imaging. Absent flow signals or blood flow limited to the hilum was categorized as benign. Nonhilar blood flow with spotted, peripheral, or mixed types of vascularization was categorized as malignant. RTE was performed for the targeted node using the same probe. Manual light compression and decompression of the target LN by the transducer were performed to achieve an optimal image. Patients were asked to hold their breath and avoid swallowing during the examination to minimize motion of LNs. The elastographic box contained the LN and adjacent sternocleidomastoid muscle for each patient. Elastograms obtained with quality factor score ≥60 were included in the study. Color map settings with red coded as hard area and blue coded as soft area were used. The images were displayed on split screen mode with US gray-scale images on the left and elastogram images on the right. The best-fit B-mode US elastogram image pairs were selected for analysis. The elasticity patterns were categorized on a 5-point scale described by Alam *et al*.[12] [Table 1]. LNs showing type 1 and 2 elastography patterns were considered benign, while those with types 3, 4, and 5 were categorized as malignant.

For ARFI imaging, the targeted LN on B-mode image was identified using a region of interest, characterized by a fixed box [Figures 1-5]. Three measurements of shear wave velocity (SWV) were performed, and the average was calculated. SWV was expressed in meter/second.

Table 1: Elastographic patterns of lymph nodes

Patterns	Description
1	Absent or very small hard area
2	Small, scattered hard areas, hard area <45% of LN
3	Hard area ≥45% of LN
4	Peripheral hard area and central soft area
5	Hard area occupying entire LN

LN: Lymph node

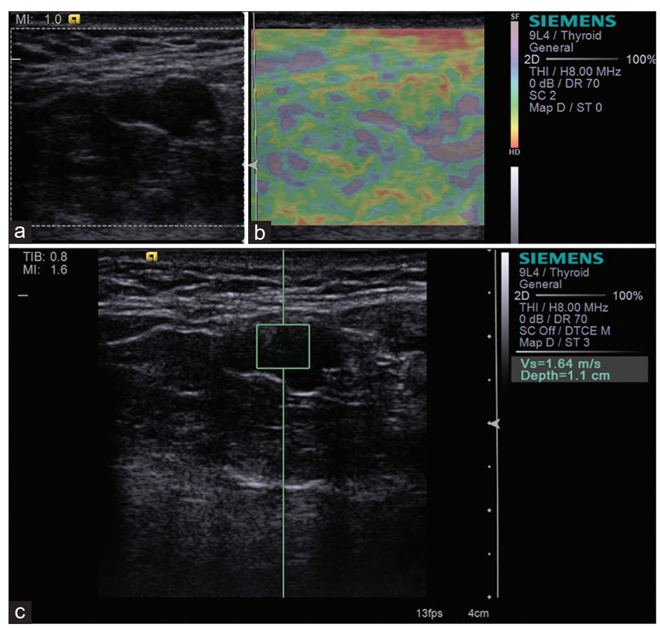

Figure 1: (a) B-mode ultrasound showing oval hypoechoic lymph node with irregular margins and absent hilum, (b) elastography image showing absent or very small hard area corresponding to pattern 1, and (c) acoustic radiation force impulse imaging shows a shear wave velocity of 1.64 m/s in the boxed area. Histopathology was suggestive of tuberculous lymphadenitis

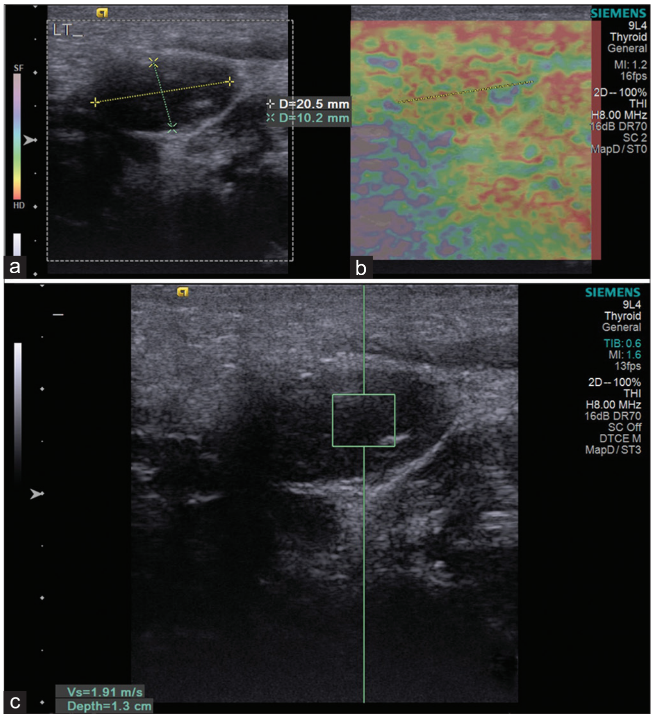

Figure 2: (a) B-mode ultrasound showing oval hypoechoic lymph node, (b) elastography image showing small, scattered hard areas corresponding to pattern 2, and (c) acoustic radiation force impulse imaging shows a shear wave velocity of 1.91 m/s in the boxed area. Histopathology was suggestive of reactive lymphadenitis

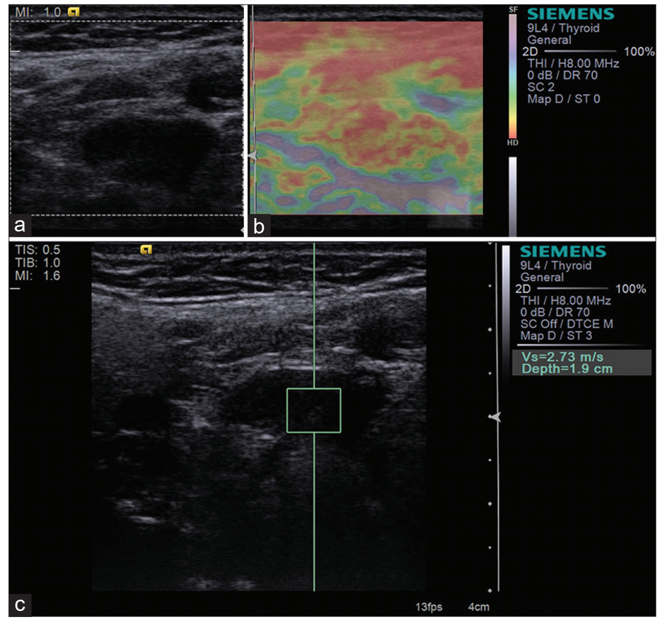

Figure 3: (a) B-mode ultrasound showing oval hypoechoic lymph node with loss of fatty hilum, (b) elastography image showing hard area ≥45% of lymph node corresponding to pattern 3, and (c) acoustic radiation force impulse imaging shows a shear wave velocity of 2.73 m/s in the boxed area. Histopathology revealed metastatic lymph node from carcinoma breast

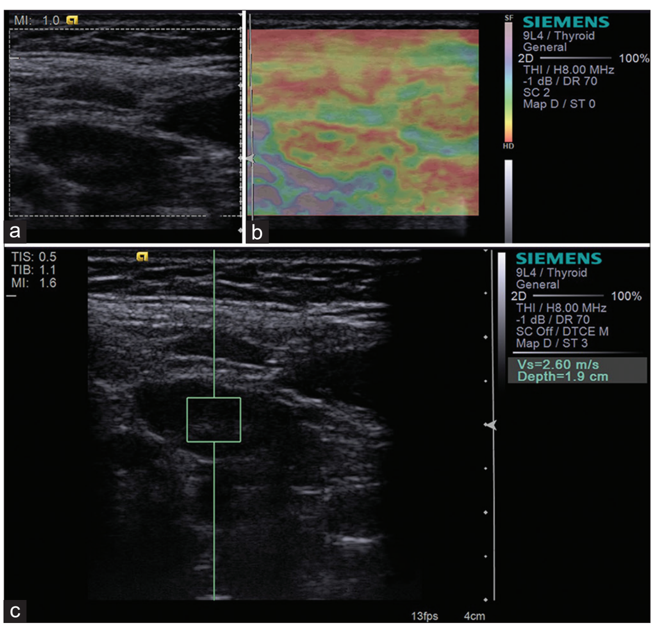

Figure 4: (a) B-mode ultrasound showing oval hypoechoic lymph node with loss of fatty hilum, (b) elastography image showing peripheral hard area and central soft area corresponding to pattern 4, and (c) acoustic radiation force impulse imaging shows a shear wave velocity of 2.60 m/s in the boxed area. Histopathology revealed metastatic lymph node from mucoepidermoid carcinoma parotid

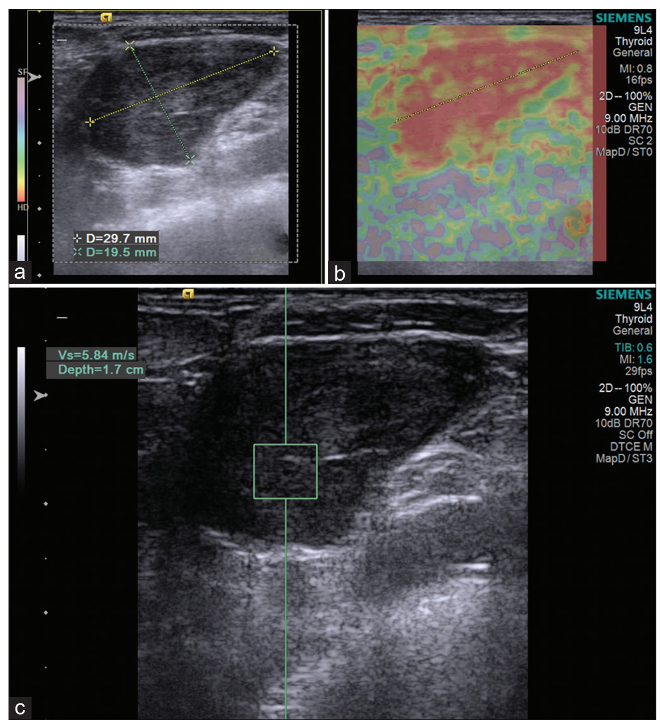

Figure 5: (a) B-mode ultrasound showing hypoechoic lymph node with irregular margins and absent hilum, (b) elastography image showing hard area occupying entire lymph node corresponding to pattern 5, and (c) acoustic radiation force impulse imaging shows a shear wave velocity of 5.84 m/s in the boxed area. Histopathology revealed metastatic lymph node from small cell carcinoma lung

Following elastography, all patients underwent surgical excision of the LN after cutaneous marking under US guidance. Histopathologic analysis of the LN was taken as the diagnostic standard of reference.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences version 24 (SPSS Inc., Chicago, IL, USA). Descriptive statistics was presented as mean ± standard deviation. Qualitative variables were presented in the form of frequency and percentages. Chi-square test was used to know the association between categorical variables. The diagnostic sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated with histopathologic analysis as reference standard. For analyzing the combined diagnostic performance of B-mode and Doppler, scores were assigned for five criteria: S/L ratio (ratio ≤0.5, score of 1: >0.5, 2), hilum (present, 1; absent, 2), borders (regular, 1; irregular, 2), echogenicity (homogenous, 1; heterogeneous, 2), and blood flow (hilar, 1; nonhilar, 2). The score for each LN was determined by adding the individual scores. A statistically supported cutoff line was set between scores 6 and 7. LNs with score <6 were categorized as benign, and 7–10 were categorized as malignant. Student *t*-test was performed to evaluate for significant difference in SWV values between benign and malignant LNs. A receiver operating characteristic (ROC) curve analysis was applied to obtain the optimal cutoff value for SWV to differentiate between benign and malignant LNs. Statistical significance was set at $P < 0.05$.

Results

The age of the patients ranged from 12 to 75 years (mean: 45.4 ± 16.9 years). About 52% (n = 26) were female and 48% (n = 24) were male. Of the 50 LNs examined, 33 (66%) were benign and 17 (34%) were malignant on histopathology. Of the 33 benign LNs, 27 had been reported as reactive and six as tuberculous lymphadenitis. Among the 17 malignant nodes, 15 were metastatic and two were due to lymphoma. Metastatic nodes were secondary to carcinoma lung, 4; parotid, 2; thyroid, 1; stomach, 1; breast, 1; poorly differentiated carcinoma from occult primary, 1; and head-and-neck squamous cell carcinoma, 5.

The US characteristics of the LNs and their diagnostic sensitivity, specificity, PPVs and NPV s, and accuracy are shown in Table 2. There were no significant differences between the benign and malignant LNs with respect to S/L ratio and echogenicity ($P = 0.273$ and $P = 0.623$, respectively). Hilum was found to be abnormal in all the 17 malignant LNs studied. Almost 81.8% of benign LNs (n = 27) had regular borders, whereas only 23.5% (n = 4) of malignant LNs had regular borders ($P = 0.000$). Among all B-mode parameters, borders of LN had the highest diagnostic accuracy (80%), while echogenicity was found to have the least accuracy (48%). On color Doppler evaluation, nearly 72% (n = 24) of benign nodes showed hilar flow compared to 35% (n = 6) of malignant nodes ($P = 0.010$).

Table 3 shows the correlation of elastographic pattern and histopathologic diagnosis of LNs. Majority of benign LNs (n = 31) had elastography patterns 1 and 2, while majority of malignant LNs (n = 16) had patterns 3–5. Higher elastographic pattern was significantly associated with malignant histopathology ($P = 0.000$).

The diagnostic performance of combined modalities (B-mode and color Doppler) and elastography is shown in Table 4.

The mean SWV of benign LNs was 1.670 ± 0.367 m/s. Metastatic LNs were significantly stiffer with mean SWV of 2.965 ± 0.826 m/s ($P = 0.000$). Figure 6 shows the ROC curve for SWVs measured using ARFI imaging in the differentiation of benign and malignant LNs. The best cutoff value for differentiating benign from malignant LNs was estimated to be 2.05 m/s with sensitivity of 88.2%, specificity of 84.8%, and area under the curve equal to 0.949 (95% confidence interval [CI]: 0.70–1.20).

Table 2: Ultrasound characteristics of lymph nodes and their diagnostic performance

US criteria	Benign LNs (n=33)	Malignant LNs (n=17)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
S/L ratio							
≤0.5	15 (45.4)	5 (29.4)	70.5	45.4	40	75	54
>0.5	18 (54.6)	12 (70.6)					
Hilum							
Present	22 (66.7)	0	100	66.6	60	100	78
Absent	11 (33.3)	17 (100)					
Borders							
Regular	27 (81.8)	4 (23.5)	68.4	87.1	76.4	81.8	80
Irregular	6 (18.2)	13 (76.5)					
Echogenicity							
Homogeneous	16 (48.5)	7 (41.2)	41.1	51.5	30.4	62.9	48
Heterogeneous	17 (51.5)	10 (58.8)					
Color Doppler							
Hilar	24 (72.8)	6 (35.3)	64.7	72.7	55	80	70
Nonhilar	9 (27.2)	11 (64.7)					

US: Ultrasound, LNs: Lymph nodes, S/L ratio: Ratio of short-axis diameter to long-axis diameter, PPV: Positive predictive value, NPV: Negative predictive value

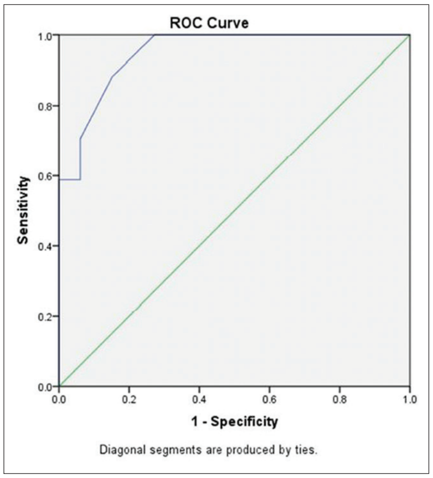

Figure 6: Receiver operating characteristic curve for shear wave velocities measured using acoustic radiation force impulse imaging in the differentiation of benign and malignant lymph nodes. The area under the curve was 0.949

Discussion

In this prospective study from India, we evaluated the performance of RTE in classification of benign and malignant cervical LNs. Our results indicate that RTE has a high specificity and diagnostic accuracy for identification of malignant LNs.

Although B-mode US is the most extensively used method for classification of cervical LNs because of its noninvasiveness and easy accessibility, specific criteria for distinguishing benign and malignant LNs are yet unclear. The association of signs often produces a highly suggestive appearance in most cases. In our study, the accuracy rate in distinguishing benign and malignant LNs was greatest for borders of LN (80%) and least for echogenicity (48%).

There were no significant differences between the benign and malignant LNs with respect to S/L ratio in our study. In contrast, several studies have noted S/L ratio >0.5 or a rounded shape to be associated with malignancy.[12,20] However, shape of LN can be misleading as nodes in nonmalignant conditions such as tuberculosis and Rosai–Dorfman disease have also been described as round.[21]

Our criterion of regular versus irregular borders revealed a diagnostic accuracy of 80%. Some other studies have categorized the LN borders as sharp and unsharp.[22,23] In a study by Khanna *et al*. from India, irregular margins were found in 7% of reactive LNs versus 55% of metastatic and 66% of tubercular nodes.[24] The absence of visible hilum due to replacement or effacement is considered as an important criterion for malignant LNs and has been reported by several authors.[12,13,25] In our study, all the 17 malignant LNs had no visible hilum, thus showing 100% sensitivity and NPV.

We observed a statistically significant difference in the vascular patterns between benign and malignant LNs ($P = 0.010$). Our observations can be comparable to that of Misra *et al*. and several other authors who have noted significant difference in vascularity between benign and malignant LNs.[13,26] In our study, the accuracy of vascularity of LN in predicting malignancy was 70%.

Table 3: Correlation of elastographic pattern and histopathologic diagnosis of lymph nodes

Elastogram pattern	Benign (n=33)	Malignant (n=17)	Total (n=50)
1	5	0	5
2	26	1	27
3	1	2	3
4	1	4	5
5	0	10	10

Table 4: Diagnostic performance of elastography and combined evaluation (B-mode and color Doppler)

Performance measure	Elastography	Combined B-mode and Doppler
Sensitivity (%)	94.1	94.1
Specificity (%)	93.9	81.2
PPV (%)	88.9	72.7
NPV (%)	96.9	96.4
Accuracy (%)	94	86

PPV: Positive predictive value, NPV: Negative predictive value

Even though combined B-mode US and Doppler could be potentially useful in differentiating reactive from malignant LNs, this modality may not have definite diagnostic value because of some overlapping sonographic appearances of benign and malignant nodes. Fine-needle aspiration cytology (FNAC) in the evaluation of cervical LNs has been reported to have a sensitivity of 82% and specificity of 97%.[27] However, FNAC is invasive and does not always provide a conclusive diagnostic result. Core needle biopsy from cervical LNs is also difficult owing to their relatively small size and potential injury to adjacent vascular structures.

RTE being noninvasive, has been suggested to be an adjunctive imaging tool to conventional US and could potentially reduce unnecessary biopsies.[28] Few prospective and retrospective studies concerning strain elastography of cervical LNs have been published in the literature.[29] While some have performed the measurement of elasticity scores (ES), some have measured both ES and strain ratio.

In our study, we used a 5-point scale described by Alam *et al*. to categorize the elasticity patterns. Accordingly, LNs showing types 1 and 2 elastography pattern were considered benign, while those with types 3, 4, and 5 were categorized as malignant. Nearly, 93.9% of benign LNs (n = 31) had a score of 1 or 2, while 94.1% of malignant LNs (n = 16) had a score of 3–5. The sensitivity, specificity, and accuracy of elastography were 94.1%, 93.9%, and 94%, respectively.

Alam *et al*. evaluated 85 cervical LNs (53 metastatic and 32 reactive) using 5-point elasticity scale and documented 83% sensitivity, 100% specificity, and 89% accuracy in differentiating metastatic from reactive LNs.[12] Bhatia *et al*. evaluated 74 cervical LNs (37 malignant and 37 benign) using RTE.[17] Dynamic cine loops of elasticity imaging were qualitatively scored on a 4-point elasticity scale by three independent observers. Median ES for benign and malignant nodes was 2 and 3, respectively. A cutoff ES score of ≥2 achieved only 62.2% sensitivity, 83.8% specificity, and 73% accuracy for malignancy. Fair to good interobserver agreement was noted in their study.

Higher accuracy rates observed in our study can be attributed to the fact that there were very few cases of lymphoma ($n = 2$) and tuberculous adenitis ($n = 6$) in our study. Lymphomas have been reported to show low stiffness from an elastographic point of view because of the large size and homogeneous structure of LNs which can produce false-negative results for malignancy.[30] Granulomatous lymphadenitis associated with tuberculosis may demonstrate calcification, scarring, or necrosis and therefore show areas of greater stiffness (false positive).[14]

Ying *et al*. performed a meta-analysis to evaluate the performance of RTE for diagnosis of malignant LNs.[29] Nine studies including 835 LNs were analyzed. The pooled sensitivity and specificity for ES in diagnosing malignant LNs were 74% (95% CI: 66%–81%) and 90% (95% CI: 82%–94%), respectively.

In the present study, we were able to obtain greater specificity, PPV, and accuracy with RTE than conventional US and Doppler for detecting malignant LNs from diverse primary sites. Hence, RTE with its fairly high specificity and diagnostic accuracy can reduce unnecessary invasive procedures for diagnosis of malignant LNs. However, it cannot replace the conventional B-mode US and Doppler because it is dependent on the machine as well as operator's expertise since excessive compression can cause nonaxial displacement and change the tissue stiffness. This in turn can affect the accuracy of the software's correlation algorithms. Furthermore, elastography is not useful for calcified LNs and those with cystic degeneration.

Relatively, few clinical studies have evaluated ARFI in the assessment of malignant cervical LNs.

In our study, ARFI imaging revealed higher SWV for malignant LNs than benign ones. The cutoff value of 2.05 m/s had sensitivity of 88.2% and specificity of 84.8% in identifying malignant LNs. Our results are comparable to that of Fujiwara *et al*. who evaluated SWVs of 42 cervical LNs using ARFI.[31] Of the numerous cutoff values tested, a SWV cutoff value of 1.9 m/s best distinguished between reactive and malignant LNs. Their criterion of SWV >1.9 m/s had 95.0% sensitivity and 81.8% specificity. According to a recent meta-analysis of nine ARFI imaging studies that included 1084 LNs, the pooled sensitivity and specificity values for detecting malignancies were 87% (95% CI: 83%–91%) and 88% (95% CI: 82%–92%), respectively.[19]

Our study has few limitations. The sample size was small, and only enlarged LNs were included. Strain elastography using free hand compression is dependent on the compression technique, and excessive compression can alter tissue stiffness. A single expert radiologist performed all the elastograms, and no interobserver variability was studied. However, studies have reported fair to almost perfect interobserver agreement in strain elastography.[6]

Head-and-neck cancers account for nearly one-third of the cancer burden in India, and it is a well-known fact that status of cervical LN is the single most important prognostic factor in squamous cell carcinoma of the head and neck.[32] To the best of our knowledge, this is the first study from India to document the diagnostic performance of elastography in evaluation of cervical lymphadenopathy, and it has shown encouraging results.

Conclusion

Elastography has high diagnostic accuracy in differentiating benign and malignant cervical LNs and can be an effective noninvasive adjunctive tool in the evaluation of cervical lymphadenopathy. It is potentially useful in selecting the LN with high probability of malignancy, on which FNAC/biopsy can be performed, thereby reducing sampling errors. ARFI imaging can be a useful technique for differentiating benign from malignant cervical LNs.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Chong V. Cervical lymphadenopathy: What radiologists need to know. Cancer Imaging 2004;4:116-20.
2. Na DG, Lim HK, Byun HS, Kim HD, Ko YH, Baek JH. Differential diagnosis of cervical lymphadenopathy: Usefulness of color Doppler sonography. AJR Am J Roentgenol 1997;168:1311-6.
3. Ghafoori M, Azizian A, Pourrajabi Z, Vaseghi H. Sonographic evaluation of cervical lymphadenopathy; comparison of metastatic and reactive lymph nodes in patients with head and neck squamous cell carcinoma using gray scale and Doppler techniques. Iran J Radiol 2015;12:e11044.
4. Leboulleux S, Girard E, Rose M, Travagli JP, Sabbah N, Caillou B, *et al.* Ultrasound criteria of malignancy for cervical lymph nodes in patients followed up for differentiated thyroid cancer. J Clin Endocrinol Metab 2007;92:3590-4.
5. Gupta A, Rahman K, Shahid M, Kumar A, Qaseem SM, Hassan SA, *et al.* Sonographic assessment of cervical lymphadenopathy: Role of high-resolution and color Doppler imaging. Head Neck 2011;33:297-302.
6. Choi YJ, Lee JH, Baek JH. Ultrasound elastography for evaluation of cervical lymph nodes. Ultrasonography 2015;34:157-64.
7. Thomas A, Fischer T, Frey H, Ohlinger R, Grunwald S, Blohmer JU, *et al.* Real-time elastography – An advanced method of ultrasound: First results in 108 patients with breast lesions. Ultrasound Obstet Gynecol 2006;28:335-40.

8. Taylor LS, Rubens DJ, Porter BC, Wu Z, Baggs RB, di Sant'Agnese PA, *et al.* Prostate cancer: Three-dimensional sonoelastography for *in vitro* detection. Radiology 2005;237:981-5.
9. Friedrich-Rust M, Ong MF, Herrmann E, Dries V, Samaras P, Zeuzem S, *et al.* Real-time elastography for noninvasive assessment of liver fibrosis in chronic viral hepatitis. AJR Am J Roentgenol 2007;188:758-64.
10. Asteria C, Giovanardi A, Pizzocaro A, Cozzaglio L, Morabito A, Somalvico F, *et al.* US-elastography in the differential diagnosis of benign and malignant thyroid nodules. Thyroid 2008;18:523-31.
11. Thomas A, Kümmel S, Gemeinhardt O, Fischer T. Real-time sonoelastography of the cervix: Tissue elasticity of the normal and abnormal cervix. Acad Radiol 2007;14:193-200.
12. Alam F, Naito K, Horiguchi J, Fukuda H, Tachikake T, Ito K. Accuracy of sonographic elastography in the differential diagnosis of enlarged cervical lymph nodes: Comparison with conventional B-mode sonography. AJR Am J Roentgenol 2008;191:604-10.
13. Turgut E, Celenk C, Tanrivermis Sayit A, Bekci T, Gunbey HP, Aslan K. Efficiency of B-mode ultrasound and strain elastography in differentiating between benign and malignant cervical lymph nodes. Ultrasound Q 2017;33:201-7.
14. Teng DK, Wang H, Lin YQ, Sui GQ, Guo F, Sun LN. Value of ultrasound elastography in assessment of enlarged cervical lymph nodes. Asian Pac J Cancer Prev 2012;13:2081-5.
15. Lo WC, Cheng PW, Wang CT, Liao LJ. Real-time ultrasound elastography: An assessment of enlarged cervical lymph nodes. Eur Radiol 2013;23:2351-7.
16. Acu L, Oktar SÖ, Acu R, Yücel C, Cebeci S. Value of ultrasound elastography in the differential diagnosis of cervical lymph nodes: A comparative study with B-mode and color Doppler sonography. J Ultrasound Med 2016;35:2491-9.
17. Bhatia KS, Cho CC, Yuen YH, Rasalkar DD, King AD, Ahuja AT. Real-time qualitative ultrasound elastography of cervical lymph nodes in routine clinical practice: Interobserver agreement and correlation with malignancy. Ultrasound Med Biol 2010;36:1990-7.
18. Suh CH, Choi YJ, Baek JH, Lee JH. The diagnostic performance of shear wave elastography for malignant cervical lymph nodes: A systematic review and meta-analysis. Eur Radiol 2017;27:222-30.
19. Zhang P, Zhang L, Zheng S, Yu C, Xie M, Lv Q. Acoustic radiation force impulse imaging for the differentiation of benign and malignant lymph nodes: A systematic review and meta-analysis. PLoS One 2016;11:e0166716.
20. Ahuja AT, Ying M, Ho SY, Antonio G, Lee YP, King AD, *et al.* Ultrasound of malignant cervical lymph nodes. Cancer Imaging 2008;8:48-56.
21. Ahuja AT, Ying M. Sonographic evaluation of cervical lymph nodes. AJR Am J Roentgenol 2005;184:1691-9.
22. Ying M, Ahuja A, Brook F. Sonographic appearances of cervical lymph nodes: Variations by age and sex. J Clin Ultrasound 2002;30:1-1.
23. Ahuja A, Ying M. An overview of neck node sonography. Invest Radiol 2002;37:333-42.
24. Khanna R, Sharma AD, Khanna S, Kumar M, Shukla RC. Usefulness of ultrasonography for the evaluation of cervical lymphadenopathy. World J Surg Oncol 2011;9:29.
25. Lyshchik A, Higashi T, Asato R, Tanaka S, Ito J, Hiraoka M, *et al.* Cervical lymph node metastases: Diagnosis at sonoelastography – Initial experience. Radiology 2007;243:258-67.
26. Misra D, Panjwani S, Rai S, Misra A, Prabhat M, Gupta P, *et al.* Diagnostic efficacy of color Doppler ultrasound in evaluation of cervical lymphadenopathy. Dent Res J (Isfahan) 2016;13:217-24.
27. Haque MA, Talukder SI. Evaluation of fine needle aspiration cytology (FNAC) of lymph node in mymensingh. Mymensingh Med J 2003;12:33-5.
28. Tan SM, Teh HS, Mancer JF, Poh WT. Improving B mode ultrasound evaluation of breast lesions with real-time ultrasound elastography – A clinical approach. Breast 2008;17:252-7.
29. Ying L, Hou Y, Zheng HM, Lin X, Xie ZL, Hu YP, *et al.* Real-time elastography for the differentiation of benign and malignant superficial lymph nodes: A meta-analysis. Eur J Radiol 2012;81:2576-84.
30. Lenghel LM, Bolboaca SD, Botar-Jid C, Baciut G, Dudea SM. The value of a new score for sonoelastographic differentiation between benign and malignant cervical lymph nodes. Med Ultrason 2012;14:271-7.
31. Fujiwara T, Tomokuni J, Iwanaga K, Ooba S, Haji T. Acoustic radiation force impulse imaging for reactive and malignant/metastatic cervical lymph nodes. Ultrasound Med Biol 2013;39:1178-83.
32. Shah SB, Sharma S, D'Cruz AK. Head and neck oncology: The Indian scenario. South Asian J Cancer 2016;5:104-5.