Axillary lymph node status in BIRADS 4-5 female patients: can shear wave and strain ultrasound elastography help?

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Abstract

Background: The status of axillary nodes is a determining factor of management and prognosis for patients having a recent diagnosis of breast cancer. Axillary nodes are usually evaluated by ultrasonography (US) and biopsy, if indicated. Ultrasound-guided sampling and intraoperative or sentinel nodal sampling are available options, however, are invasive and hold risks of potential complications, calling for reliable, non-invasive axillary imaging. In the current prospective study, we assessed the performance of shear wave (SWE) and strain (SE) ultrasound elastography regarding preoperative axillary assessment. Sixty axillary nodes from 60 patients (age 28–65 years, mean 49.88 ± 7.61 SD) were included, all scoring BIRADS 4–5 on sonomammography.

Results: For US, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were 100%, 66.67%, 84.78%, 100%, and 88.33%, respectively. Cortical thickness and vascularity were the most sensitive. For qualitative SWE, indices were 76.92%, 80.95%, 88.24%, 65.38% and 78.33%, respectively. Calculated cut-off for Emax was 59.3 and for Eratio was 4.56, giving statistical indices of 76.9%, 90.5%, 93.75%, 67.86%, and 81.67% for Emax and 76.9%, 100%, 100%, 70% and 85% respectively for Eratio. Both Emax and Eratio were greater for malignant (Emax 81.77 ± 1.904, Eratio 8.95 ± 5.69) than for benign nodes (Emax 37.59 ± 33.37, Eratio 2.5 ± 1.37) (P values < 0.001). For qualitative SE, sensitivity and specificity were 92.31% and 57.14%, while PPV, NPV, and accuracy were 80% each (P values < 0.001). The calculated cut-off value for SR was 3.85, giving indices of 87.2%, 76.2%, 76.19%, 87.18% and 83.33% respectively.

Conclusion: Adding elastography evaluation to conventional US positively impacts the specificity and accuracy of the preoperative axillary nodal status assessment in patients having newly diagnosed breast cancer.

Keywords: Axillary nodes, Shear wave elastography, Strain elastography, Breast cancer

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Background

Accurate preoperative assessment of the axillary nodal status in cases with recently discovered breast cancer is a crucial part of its management which involves staging, plan of treatment, and prognosis [1]. Although definitive pathologic diagnosis is invaluable for those patients, radiologic imaging represents the primary way used for staging [2]. For pathological axillary lymphadenopathy, ultrasound (US) and fine-needle aspiration are commonly used for preoperative assessment. Yet, as a result of the moderate sensitivity and false-negative results, this can lead to unessential sentinel nodal sampling, which can cause related upper limb morbidities. Therefore, a need has emerged for a non-invasive tool that can accurately stage axillary lymph nodes preoperatively [3].

Elastography is one of the advances of US which has a potential to differentiate malignant from benign tissue by measuring its elasticity. For breast US, it can be either strain elastography (SE) or shear wave elastography (SWE) [1]. Both exploit the fact that malignant tissues are usually stiffer than benign ones, and thus, elastography can be utilized to ameliorate the specificity of US diagnosis [3]. Strain elastography relies on the operating hand where it utilizes freehand compression to estimate elasticity of tissues [1]. On the contrary, SWE gives absolute elasticity quantification where qualitative analysis is done using colour-coded elastography maps that are obtained in real time, simultaneously with b-mode US images, analyzing impulses generated before and after automatically produced rhythmic vertical compressive waves [4]. Quantitative analysis is done by calculating both Emax (maximum elasticity calculated using pressure wave velocity in the examined region) and Eratio (ratio between nodal mean elasticity and its surroundings), where higher values are generally noted with stiffer/malignant lesions [5].

In this study, we evaluated the impact of adding US elastography (SWE or SE) to the preoperative evaluation of the axillary nodal status in female patients with recently diagnosed breast cancer, having a Breast Imaging Reporting Database System Score (BIRADS) score of 4 or 5 on sonomammography (SMG). We compared its results to those of conventional US, where the final histopathology served as the standard of reference.

Methods

Study population and their inclusion and exclusion criteria

This prospective study included 60 axillary lymph nodes from 60 female patients with ages ranging from 28 to 65 years (mean 49.88 years ± 7.61 SD), who presented to our institution during the time period from December 2018 to May 2019. All participating patients had breast lesions scoring BIRADS 4 or 5 on SMG, and the most suspicious node on the ipsilateral side of the breast lesion was chosen to be included in the study. The most suspicious node was chosen based on its US criteria, mainly those with focal cortical thickening, effaced hilar fat, non-ovoid shape and deranged hilar vascularity. All patients with BIRADS category 1, 2 or 3 lesions were excluded from participation. We also excluded those who were previously given neoadjuvant chemotherapy or any treatment that may affect the results of the study.

Demographic data and history taking

Patients provided informed written consents for participation, and our institutional ethical committee approval was obtained. Thorough demographic and clinical history taking were done (including name, age, marital status, offsprings, residence, phone number, diagnosis, illness duration, family history and history of previous illness). All patients underwent axillary b-mode US, SE and SWE. Examinations were performed using GE LOGIQ E9 XD clear 2.0 US scanner linear array electronic probes.

Examinations were performed and interpreted conjointly by two consultant radiologists, having more than 10 years of experience in the field of breast imaging. The results of each modality were correlated to those of final histopathology which served as a reference standard.

Conventional US imaging and interpretation

To perform the examinations, each patient was put in the oblique supine position with her ipsilateral hand placed behind the head so that her arm was in abduction and external rotation.

For conventional US, both gray scale and power/color Doppler were performed using a high-frequency linear transducer, scanning all nodes in orthogonal planes. To analyze US images, each node was assessed as regards its shape (whether ovoid or non-ovoid), presence of cortical thickening (considering a cortex measuring > 3mm as thickened), and whether this thickening is diffuse, focal, or forming an irregular mass. Nodes were also evaluated regarding their fatty hila (whether central, eccentric, effaced or not preserved) and their vascularity (whether hilar or non-hilar). Each node was classified as benign, indeterminate or malignant blinded to histopathology results.

Elastography (SWE and SE) imaging and interpretation

After US, both SE and SWE were done by putting the transducer over the examined node, utilizing contact gel and generating pressure waves (manually in SE and automatically in SWE). The patient was instructed to hold her breath for 10 to 20 s until the image stabilized. The built-in box was set in a form that it included the region of interest (ROI) of the examined node and adjacent normal tissue, followed by mild axial compression

Table 1 Relation between the combined US criteria results and final pathology results

		Final pathology				P value
		Malignant		Benign		
		Number	%	Number	%	
Combined US criteria results	Malignant	39	100%	7	33.3%	< 0.001
	Benign	0	0%	14	66.7%	

to the examined node until the pressure index reached 3 or 4 and lasted for 2 or 3 s in a stable manner.

SE was done by performing manual, repeated compression and decompression in a maintained frequency over the region of interest. It gave a qualitative color-coded map of the relative stiffness of tissues, ranging from red (lowest stiffness) to blue (highest stiffness). A ROI was put on the stiffest area of the examined node, and another ROI having the same size and on the same level was put in the surrounding axillary fat in order to calculate the strain ratio (SR).

For *SWE*, the pressure waves were produced automatically without the need for manual compression. This provided a semi-transparent map of color for stiffness of tissues that ranged from blue (lowest stiffness) to red (highest stiffness), and this was superimposed on the gray scale image. Numerical values for the velocity of the pressure wave in the examined region were also provided, automatically calculating the maximum elasticity value in kilopascals (Emax). A ROI was put on the stiffest part of the examined node and a similar one, having the same size, was placed at the same level in the adjacent fat, in order to calculate the ratio between the mean value of elasticity in the node of interest to that in the surrounding fat. Finally, we saved the image with the best quality and least artifacts to include in the study.

Color-coded map scoring
To analyze elastography images, the color-coded map of each examined node was evaluated using a modulated system of scoring, based on the percentage of relatively stiffer areas (areas of cortical hypoechogenicity) that scales from 1 to 4 depending on the nodal elastogram pattern, as follows:

- Score 1: Blue areas in case of SWE or red areas in case of SE occupying nearly all of the cortex

- Score 2: Red areas in case of SWE or blue areas in case of SE occupying < 50% of the cortex
- Score 3: Red areas in case of SWE or blue areas in case of SE occupying > 50% of the cortex
- Score 4: Red areas in case of SWE or blue area in case of SE occupying nearly all of the cortex

Nodes scoring 1 or 2 were considered as benign, whereas those scoring 3 or 4 were considered as metastatic. The cut-off values for SR (in case of SE) and for both Emax and Eratio (in case of SWE) were also calculated.

Statistical analysis
Finally, the blinded results for US, SE and SWE (qualitative analysis, SR, Emax and Eratio) were correlated to those of pathology using the Statistical Package for the Social Sciences, where quantitative data was expressed as mean, standard deviation (SD), median, minimum and maximum. Qualitative data was expressed as frequency and relative frequency. Comparisons between quantitative variables were done using the Mann-Whitney test (non-parametric). While for comparing qualitative data, Chi square (χ2) test was performed. Exact test was used instead when the expected frequency was less than 5. Standard diagnostic indices (sensitivity, specificity, PPV, NPV and efficacy) were calculated, and receiver operating characteristics curve (ROC curve) with area under curve (AUC) analysis was performed to detect the best cut-off value of different parameters for malignancy detection, while logistic regression was done to predict malignancy by combination of US and elastography. *P* values less than 0.05 were considered statistically significant.

Results
This prospective study included 60 axillary nodes from 60 female patients (with ages ranging from 28 to 65

Table 2 Relation of the results of colour-coded map scoring of SWE (qualitative analysis) and those of final pathology

		Final pathology				P value
		Malignant		Benign		
		Number	%	Number	%	
Color map score	Malignant	30	76.9%	4	19%	< 0.001
	Benign	9	23.1%	17	81%	

Table 3 Lymph node distribution according to Emax and Eratio values

	Final pathology										P value
	Benign					Malignant					
	Number	Mean	SD	Minimum	Maximum	Number	Mean	SD	Minimum	Maximum	
Emax	21	37.59	24.08	8	115	39	81.77	33.37	27.5	156	< 0.001
Eratio	21	2.5	1.37	0.7	4.5	39	8.95	5.69	0.56	24.8	< 0.001

years, mean 49.88 ± 7.61 SD) having lesions categorized as BIRADS 4 or 5 on SMG. Final pathology revealed that 21 out of the examined 60 nodes were not metastatic, while 39 were metastatic.

Analysis of axillary nodes according to conventional US
To analyze nodal b-mode US images, the following were studied:

1. *The distribution of nodes according to their shape (ovoid/non-ovoid)* where 40 out of 60 examined nodes were ovoid (66.7 %) and 20 were non-ovoid (33.3%).

Considering an 'ovoid shape' as a benign descriptor and 'non-ovoid' as a malignant one, the calculated sensitivity, specificity, PPV, NPV and accuracy were 51.28%, 100%, 100%, 52.5% and 68.33% respectively, with a significant *P* value < 0.001.

2. *The distribution of nodes according to the presence of fatty hila (central/effaced/eccentric/totally infiltrated)*, where 31 out of the examined 60 nodes had central hila (51.7%), 13 had effaced hila (21.7%), 8 had eccentric hila (13.3 %), and 8 had totally infiltrated (non-preserved) hila (13.3%).

Considering a 'central hilum' as a benign descriptor and 'effaced', 'eccentric' or 'totally infiltrated' hila as malignant ones, sensitivity, specificity, PPV, NPV and accuracy were 71.79%, 95.24%, 96.55%, 64.52% and 80%, respectively, with significant *P* value < 0.001.

3. *The distribution of nodes according to the presence of cortical thickening* where by ROC curve analysis, the calculated cut-off value for cortical thickness that can differentiate between benign and malignant nodes was 3 mm. Those with thickened cortexes were then distributed according to the shape of cortical thickening, into 'diffuse', 'focal', or 'thickening forming an irregular mass'.

It was found that 15 out of the examined 60 nodes had no cortical thickening (25%), 26 had diffuse thickening (43.3%), 15 had focal thickening (25%),

and 4 had thickening forming an irregular mass (6.7%).

Considering 'no cortical thickening' as a benign descriptor and 'diffuse', 'focal' or 'irregular mass formation' as malignant ones, sensitivity, specificity, PPV, NPV and accuracy were 100%, 71.4%, 86.67%, 100% and 90% respectively, with a significant *P* value < 0.001.

4. *The distribution of nodes according to vascularity (hilar/non-hilar)* where 27 out of the examined 60 nodes had hilar vascularity (45%), and 33 had non-hilar vascularity (55%).

When considering 'hilar vascularity' as a benign descriptor and 'non-hilar vascularity' as a malignant one, sensitivity, specificity, PPV, NPV and accuracy were 79.49%, 90.48%, 93.94%, 70.37% and 83.33% respectively, with significant *P* value < 0.001.

5. *The distribution of nodes according to all combined US criteria*

Considering all the US criteria combined together, nodes were classified as 'benign', 'indeterminate' and 'malignant', where 14 out of the examined 60 nodes (23.3%) were diagnosed by US as benign, 23 (38.3%), as indeterminate and 23 as malignant (38.3%). The indeterminate and the malignant nodes were added together and all considered as suspicious. Therefore, 46 out of the examined 60 nodes were considered by US as suspicious (malignant), out of which 7 were proved to be benign by final pathology (false positive).

The calculated sensitivity, specificity, PPV, NPV and accuracy were 100%, 66.67%, 84.78%, 100% and 88.33% respectively, with significant *P* value < 0.001 (Table 1).

Analysis of axillary nodes according to SWE
The distribution of nodes according to the colour-coded map score of SWE (qualitative analysis)
Fifteen out of the examined 60 nodes had a score of 1 (25%) (almost all blue or green), *11* had a score of 2 (18.3%) (blue > 50%), 19 had a score of 3 (31.7%)
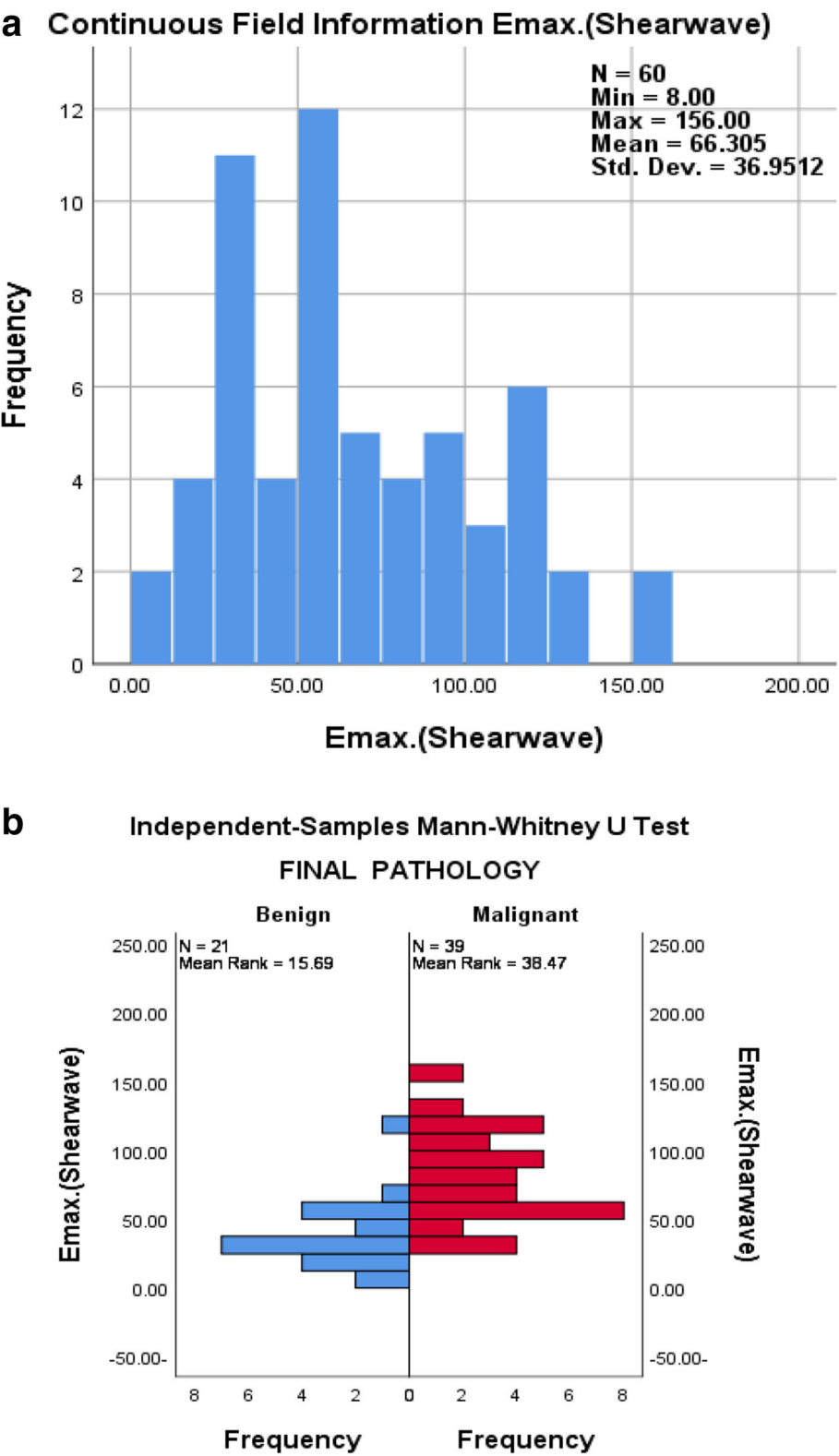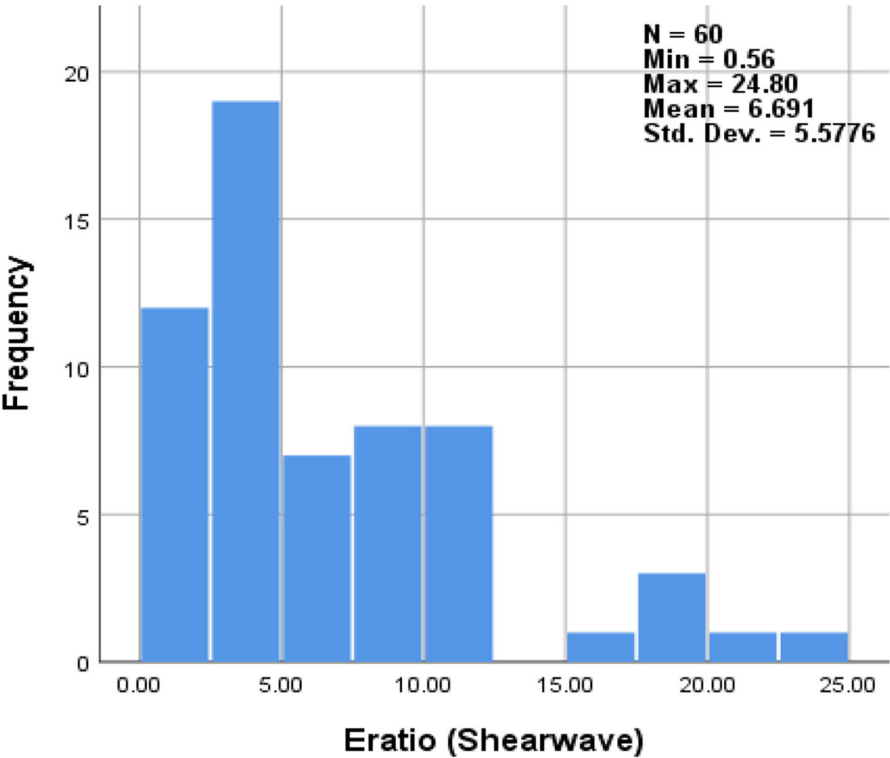
Fig. 1 a Distribution of Emax values for the examined nodes. **b** Distribution of Emax values for benign and malignant nodes

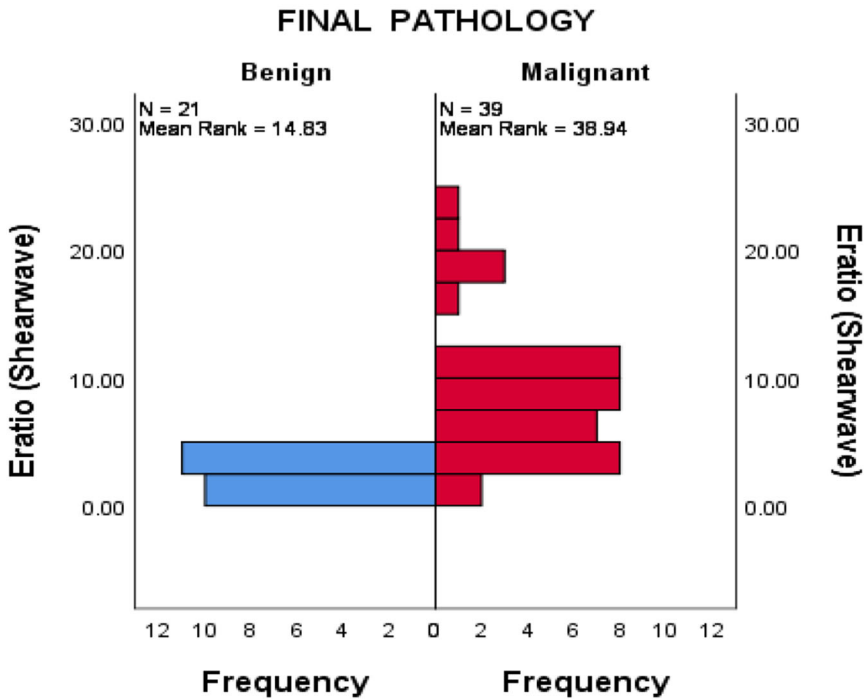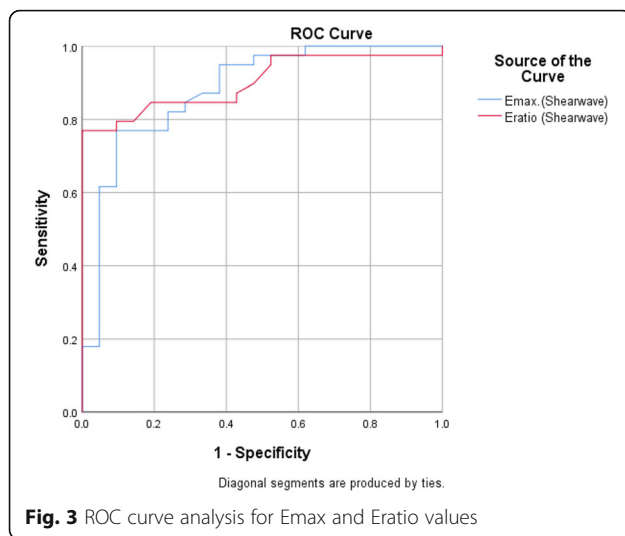**Fig. 2 a** Distribution of Eratio values for the examined nodes. **b** Distribution of Eratio values for benign and malignant nodes

Fig. 3 ROC curve analysis for Emax and Eratio values

(red > 50%) and 15 had a score of 4 (25%) (almost all red). Considering scores 1 and 2 as benign descriptors and scores 3 and 4 as malignant ones, sensitivity, specificity, PPV, NPV and accuracy were 76.92%, 80.95%, 88.24%, 65.38% and 78.33% respectively, for the results of colour-coded map scoring correlated to those of final pathology, having a significant P value < 0.001 (Table 2).

The distribution of nodes according to maximum elasticity (Emax) and elasticity ratio (Eratio) values (Table 3)

The obtained Emax values for all nodes, ranged from 8 to 156 Kpa (mean 66.3 ± 36.95) (Fig. 1a). It was noticed that the mean Emax value for malignant nodes (mean 81.77 ± 1.904) was significantly greater than that for benign nodes (mean 37.59 ± 33.37) (P value < 0.001) (Fig. 1b).

The obtained Eratio values for all nodes, ranged from 0.56 to 24.8 (mean 6.69 ± 5.58) (Fig. 2a). It was found that the mean Eratio value for malignant nodes (mean 8.95 ± 5.69) was significantly greater than that for benign nodes (mean 2.5 ± 1.37) (P value < 0.001) (Fig. 2b).

By applying a ROC curve analysis of Emax and Eratio, the true positive rate (sensitivity) was plotted against the false-positive rate (specificity) (AUC for

Emax = 0.880, AUC for Eratio = 0.902), it was found that the best cut-off point for Emax is 59.3, while that for Eratio is 4.56 (Fig. 3).

When considering the calculated cut-off value of Emax which differentiates benign and malignant nodes as 59.3, 28 out of the examined 60 (46.7%) nodes were diagnosed as benign by Emax, out of which 9 (32.1%) nodes turned out to be malignant by pathology (false negative). On the other hand, 32 out of examined 60 (53.3%) nodes were considered to be malignant by Emax, out of which 2 (6.25%) nodes turned out to be benign by pathology (false positive).

When considering the calculated cut-off value of Eratio which differentiates benign and malignant nodes as 4.56, it was found that 30 out of the examined 60 (50%) nodes were considered as benign by Eratio, out of which 9 (30%) nodes were proved to be malignant by pathology (false negative). On another hand, 30 out of the examined 60 (50%) nodes seemed to be malignant by Eratio, and all of them proved to be truly malignant by pathology (no false positives).

Considering the previous results, sensitivity, specificity, PPV, NPV and accuracy were 76.9, 90.5, 93.75, 67.86 and 81.67 respectively, for Emax, with AUC = 0.880 and P value < 0.001. Those for Eratio were 76.9, 100, 100, 70 and 85 respectively, with AUC = 0.902 and P value < 0.001.

Analysis of axillary nodes according to SE
The distribution of nodes according to the colour-coded map score (qualitative analysis)

Five out of the examined 60 nodes had a score of 1 (8.3%) (almost all red or green), 10 had a score of 2 (16.7%) (red > 50%), 29 had a score of 3 (8.3%) (blue > 50%), and 16 had a score of 4 (26.7%) (almost all blue). Considering scores 1 and 2 as benign descriptors and scores 3 and 4 as malignant ones, the calculated sensitivity and specificity were 92.31% and 57.14%, whereas the PPV, the NPV and the overall accuracy were 80% each, if correlated to the final pathology results, with a significant P value < 0.001 (Table 4).

Table 4 Relation between the qualitative SE results and the final pathology

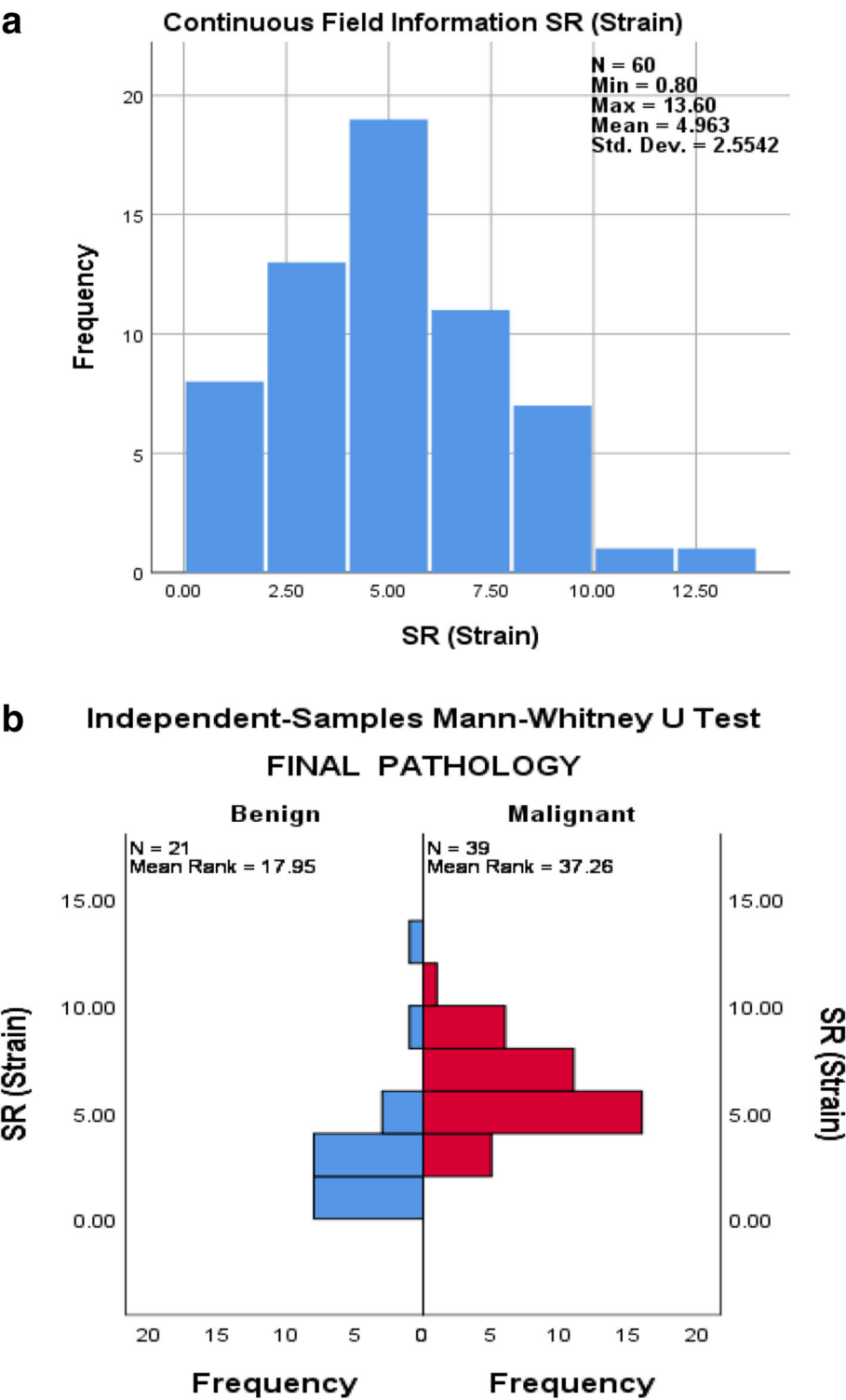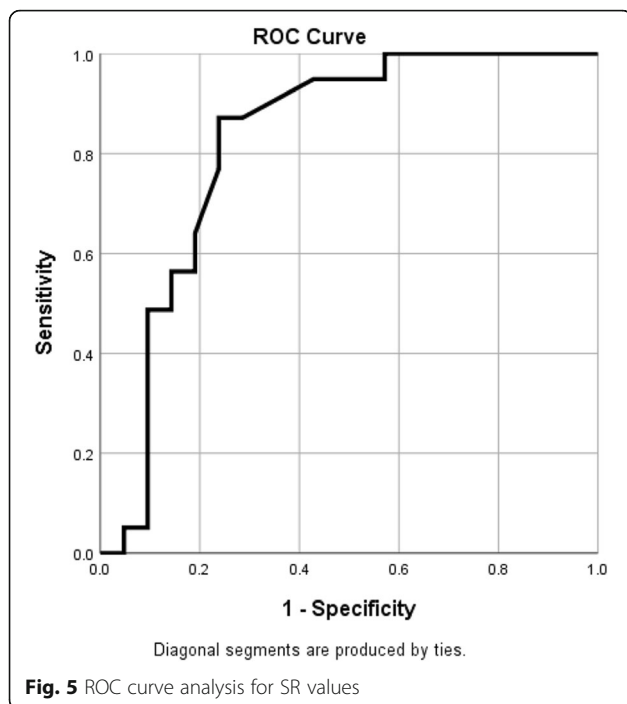|		Final pathology				P value
		Malignant		Benign		
		Number	%	Number	%	
Color map score	Malignant	36	92.3%	9	42.9%	< 0.001
	Benign	3	7.7%	12	57.1%	

Fig. 4 a Distribution of SR values for the examined nodes. **b** Distribution of SR values for benign and malignant nodes

Fig. 5 ROC curve analysis for SR values

The distribution of nodes according to SR values

The obtained SR values for all examined nodes ranged from 0.56 to 24.8 (mean 6.69 ± 5.58). It was found that mean SR values for malignant nodes (5.76 ± 1.85) were greater than those for benign ones (mean 3.48 ± 3.03) (*P* value < 0.001) (Fig. 4).

By applying ROC curve analysis (Fig. 5) for the obtained SR values (AUC = 0.822), it was found that the best cut-off point that differentiates benign from malignant nodes was 3.85. By applying this cut-off value, 21 out of the examined 60 (35%) nodes were considered as benign by SR, out of which 5/21 (23.8%) turned out to be malignant by pathology (false negative), and 39 out of the examined 60 (65%) nodes were considered as malignant by SR, out of which 5/39 (12.8%) turned out to be benign by pathology (false positive) (Figs. 6 and 7).

This resulted in 87.2% sensitivity, 76.2% specificity, 76.19% NPV, 87.18% PPV and 83.33% accuracy.

Elastography evaluation of the indeterminate node group diagnosed by b-mode US The US-diagnosed indeterminate group of lymph nodes were evaluated using each modality separately, with correlation to the final pathology results. It was noted that from the examined 60 nodes, 23 (38.3%) were categorized by US as indeterminate, out of which 7/23 (30.4%)
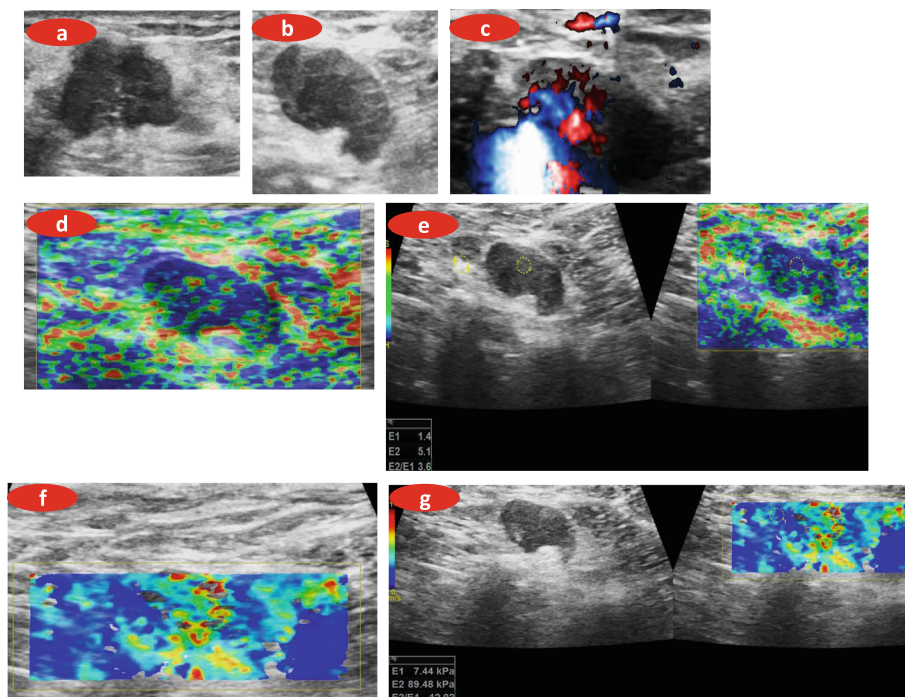

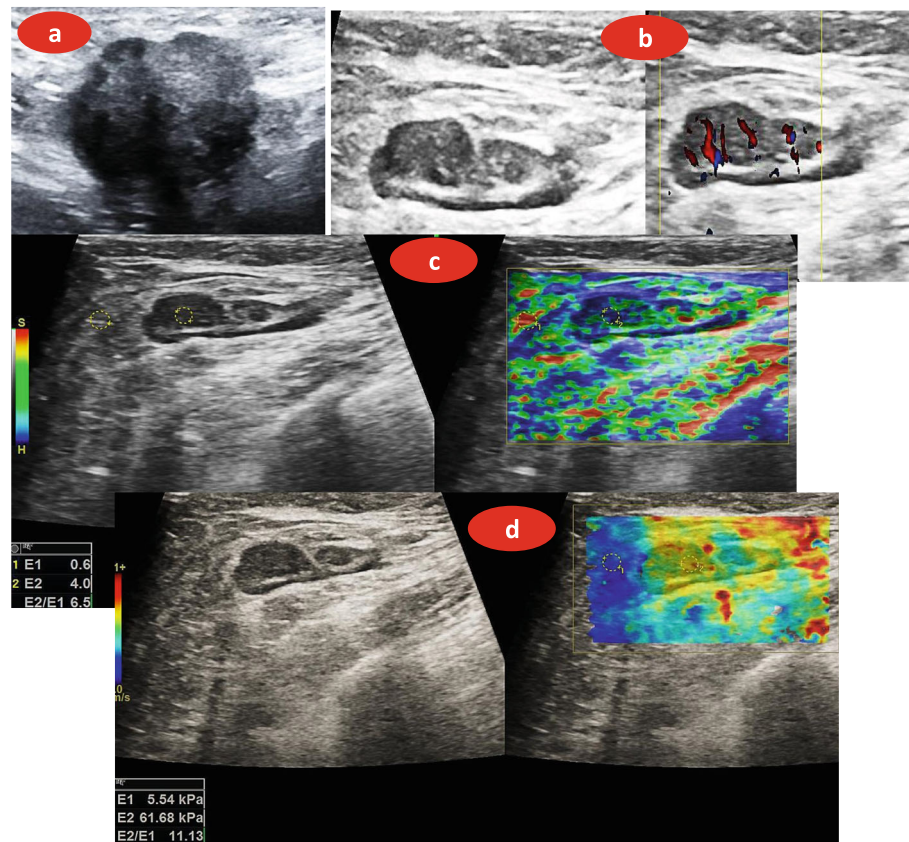Fig. 6 A pregnant 33-year-old lady presenting with a palpable breast lump

Fig. 7 A 28-year-old lady with palpable left breast lump

were pathologically proven benign (false positive), and 16/23 (69.6%) were pathologically proven malignant (true positive).

Using SR of SE changed the diagnosis of 4/23 indeterminate nodes from malignant (false positive by US) into benign (true negative by SR), which were confirmed to be truly benign by pathology (Fig. 8), having sensitivity, specificity, PPV, NPV and accuracy of 75%, 57.14%, 80%, 50% and 69.57% respectively, with significant P value < 0.001.

Using Emax of SWE changed the diagnosis of 5/23 indeterminate nodes from malignant (false positive by US) into benign (true negative by Emax), which were confirmed benign by pathology (Fig. 9). Sensitivity, specificity, PPV, NPV and accuracy were 50%, 71.43%, 80%, 38.46% and 56.52% respectively, with a significant P value < 0.001.

On the other hand, using Eratio of SWE, changed the diagnosis of 7/23 indeterminate nodes from malignant (false positive by US) into benign (true negative by Eratio), which were confirmed benign by pathology, with sensitivity, specificity, PPV, NPV and accuracy of

56.25%, 100%, 100%, 50% and 69.57% respectively, with significant P value < 0.001.

The diagnostic indices of the different imaging modalities used in the study are shown in Table 5.

Discussion

Accurate diagnosis of the axillary nodal status in cases of newly discovered breast cancer is important for proper management [1]. Imaging is an integral part of preoperative axillary staging, commonly achieved by US and US-guided sampling. In-essential sentinel nodal sampling may result in morbidity of the ipsilateral limb, which justifies the importance of increasing the accuracy of non-invasive, preoperative nodal evaluation [2].

Elastography can potentially differentiate malignant from benign tissue, via measuring its stiffness. It can increase accuracy and specificity of US evaluation [3].

In this study, we studied the additional value of adding SE or SWE to axillary US evaluation of 60 female patients who were recently diagnosed with breast cancer and scored either BIRADS 4 or 5 on SMG.
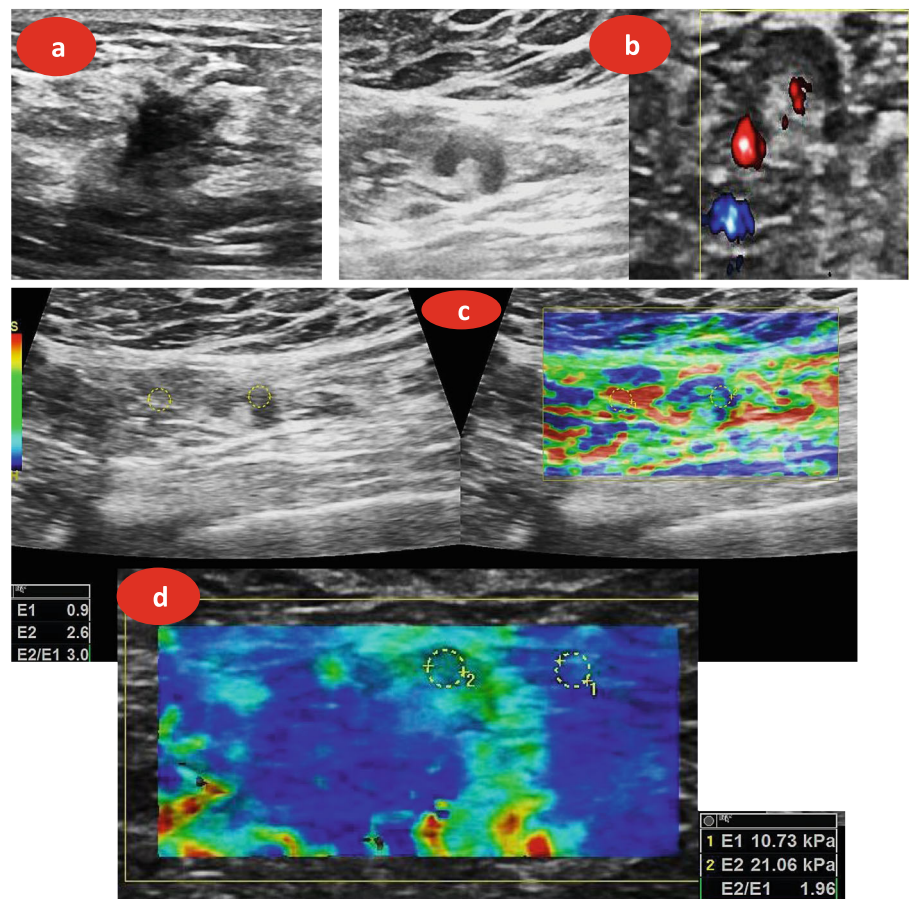
Fig. 8 A 48-year-old lady with a palpable right breast lump

Each node was classified by conventional US as either benign, indeterminate or malignant blinded to histopathology results. The US-diagnosed indeterminate group of nodes was added to the malignant group and were all together considered as suspicious (malignant). This resulted in a rather higher figure of US sensitivity (100%) to detect suspicious nodes; however, with relatively lower specificity (66.67%). Several previous researchers studied the diagnostic value of US evaluation of axillary nodes. These studies include the studies carried out by Riedel et al. [6], Gipponi et al. [7], Marino et al. [8] and Rukanskienė et al. [9].

In the current study, pathology-proven malignant nodes generally showed higher cortical thickening compared to benign ones, where it proved to be the most sensitive criterion for detecting metastatic nodes. However, its specificity was relatively lower as diffuse thickening (26 nodes) could be seen with other benign conditions where 2/26 nodes proved to be benign. Moreover, 15 nodes showed focal cortical thickening, out of which 4 were proved benign. These results match

those of several other researchers, such as Chang et al. [3] and Abe et al. [10].

Nodal vascular pattern was the second most sensitive US criterion for detecting malignant nodes (79.5% sensitivity), which agrees with the results of a previous study [3].

It was also noticed that pathology-proven malignant nodes showed effaced, eccentric or totally infiltrated fatty hila if compared with benign ones, which goes in agreement with the results of the study done by Dawoud et al. [11].

Nodal shape was the least sensitive US criterion for detecting infiltration, (51.28% sensitivity). Yet, it showed better specificity, as all pathology-proven benign nodes (21/60) retained their ovoid shape. This is rather similar to the reported results of few previous studies [1, 3].

Regarding SWE in the current study, nodes were evaluated by the colour-coded map scoring (qualitative method) and by both 'Emax' and 'Eratio' (quantitative method).
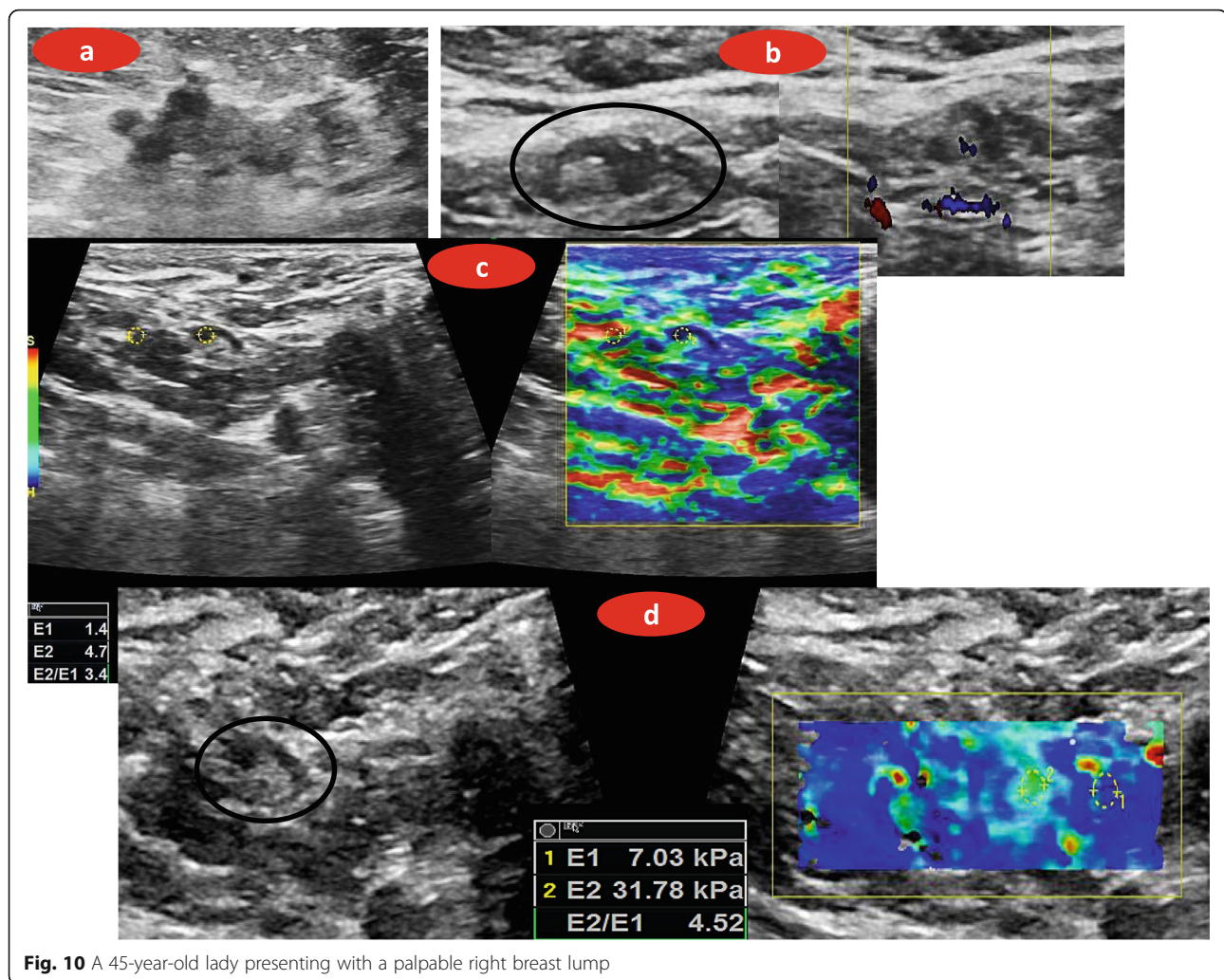
Fig. 9 A 45-year-old lady with positive maternal family history, presenting for screening

For colour-map scoring, the results of the current study showed rather lower statistical indices if compared to the quantitative assessment which showed better statistical performance. These results do not match those of Luo et al. [12] who quoted better performance of the qualitative method, if compared with the quantitative one. This may be attributed to the implementation of a different scoring system in either study.

On the other hand, Eratio values showed higher diagnostic performance indices than those of Emax which agrees with the results of Youk et al. [1].

Both Emax (range 8-156 Kpa, mean 66.3 ± 36.95) and Eratio (range 0.56–24.8, mean 6.69 ± 5.58) were generally greater for malignant nodes (Emax = 81.77 ± 1.904, Eratio = 8.95 ± 5.69) than for benign ones (Emax = 37.59 ± 33.37, Eratio = 2.5 ± 1.37), having significant *P*

Table 5 Diagnostic indices of the different modalities used in the study.

Item	TP	FN	TN	FP	Sensitivity	Specificity	PPV	NPV	Accuracy
Conventional Ultrasound	39	0	14	7	100%	66.67%	84.78%	100%%	88.33%
Qualitative SWE	30	9	17	4	76.92%	80.95%	88.24%	65.38%	78.33%
Emax (SWE)	30	9	19	2	76.9%	90.5%	93.75%	67.86%	81.67%
Eratio (SWE)	30	9	21	0	76.9%	100%	100%	70%	85%
Qualitative SE	36	3	12	9	92.31%	57.14%	80%	80%	80%
SR (SE)	34	5	16	5	87.2%	76.2%	87.10%	76.19%	83.33%

Fig. 10 A 45-year-old lady presenting with a palpable right breast lump

values < 0.001. This agrees with those of several other studies [13, 14].

Regarding SE, all nodes included in the current study were evaluated by colour-coded map scoring (qualitative) and strain ratio (SR) (semi-quantitative).

For colour-coded map scoring of SE, a scoring system based on the percentage of hard portions within a node was used, where if those hard portions represented more than 50%, this node was considered as positive for malignancy. A similar scoring system was used by Chang et al. [3] (Figs. 10 and 11).

On the other hand, SR values were significantly higher for metastatic axillary nodes (mean 5.76 ± 1.85 SD) than for non-metastatic ones (mean 3.48 ± 3.03 SD; *P* value = 0.001), with a calculated cut-off value of 3.85. These results are similar to those of several other studies [4, 15].

Comparing the different modalities used in the current study, it was noticed that conventional US

had the highest sensitivity (100%) and accuracy (88.33%), however with lower specificity (66.67%). Elastography had better specificity, but less sensitivity which matches the results of Xu et al. [3]. It can be concluded that elastography, either SWE or SE, is a non-invasive technique that can be added to the preoperative axillary evaluation of patients with recently discovered breast cancer. It can add better specificity to axillary characterization, which agrees with the results of several previous studies [12–14, 16, 17].

Limitations

One of the limitations of the current study is including only the most suspicious node on the ipsilateral side of the primary tumour and correlating it to the results of histopathology.

Another limitation of this study was combining both the US-considered indeterminate and malignant groups together, to form a suspicious group. In this way, any

Fig. 11 A 55-year-old lady with a palpable left breast lump

lymph node that had any off-classic criteria was considered in the suspicious group which may account for the higher figure of sensitivity of US and relatively lower specificity.

We were also faced with problems concerning the optimal extent of compression of tissues that affects elasticity images and scores, which needs experience with the technique in order to get reproducible results. It was noticed that Eratio figures were the least affected by this difference as shear wave values equally change in both a lesion and its surroundings.

Conclusion

Precise evaluation of the axillary status in patients with newly diagnosed breast cancer is crucial for accurate management. Conventional axillary US is highly sensitive for the detection of abnormal axillary nodes, yet its specificity can be augmented by combining it with elasticity evaluation which reflects on decreasing the number of diagnosed indeterminate nodes. This can help in eliminating under or over staging of the axillary status in each patient which can lead to better tailoring of management selection. Elastography is a non-invasive additional tool that can be added to

preoperative ultrasound nodal evaluation in order to increase the diagnostic confidence. However, as it still presents variable diagnostic performance, further standardisation of techniques is required to give reproducible results.

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