Breast Elastography: Our Initial Experience with Strain and Shear Wave Elastography

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ABSTRACT

Fifth edition of American College of Radiology (ACR) - Breast Imaging Reporting and Data System (BIRADS) was published in 2013. ACR-BIRADS is used as a quality assurance tool to standardize reporting, decrease confusion in image interpretation and to facilitate outcome monitoring. BIRADS is also used to guide management decisions. BIRAD 1, 2 and 3 lesions are generally kept on follow up and BIRADS 4 and 5 lesions are generally considered for Fine Needle Aspiration Cytology (FNAC)/Biopsy for Histopathological analysis. More than 80% of BIRADS 4a lesions are proven benign on Histopathological analysis. Hence, now many authors are advocating that breast lesions until BIRADS 4a should be kept on follow up and breast lesions in BIRADS 4b, 4c, 5 and 6 category should be considered for FNAC/Biopsy. We hereby are sharing our initial experience with Strain Elastography (SE) and Shear Wave Elastography (SWE) of breast masses.

INTRODUCTION

Elastography of Breast masses

Breast lesions are initially characterized on grey scale and colour doppler based on suspicious features[1,2]. But, this method of differentiating benign from malignant lesions has significant limitations including high false positive rates. Most lesions biopsied based on grey scale and colour Doppler findings turn out to be benign on Histopathological evaluation.

First practical equipment for Elastography was released in 2003[3]. Elastography is based on basic presumption that benign masses are soft, can be deformed and have strain when external pressure is applied to these masses. Malignant masses are hard, can't be deformed and have little or no strain when external pressure is applied to these masses. Elastography can be of two types:

1. Strain Elastography and

2. Shear Wave Elastography

Strain Elastography (SE)

In SE, breast masses are subjected to compressive force by external pressure[4]. As in most cases, this external pressure is applied by manual compression; this method is subject to errors due to different force being applied each time by same/different operator. Moreover, this is a qualitative method of evaluating breast masses, wherein we compare Elastographic image with grey scale image and evaluate two features:

1. Ratio of largest diameter on Elastographic image with largest diameter on grey scale. If this ratio is 1 or more, then mass is considered malignant.

2. Comparison of grey scale/colour image as seen on Elastography with scale available on Elastographic image. These images are evaluated according to classification given by ItohA et al[5].

Itoh Score 1	High strain of entire lesion
Itoh Score 2	High strain most of the lesion
Itoh Score 3	High peripheral strain
Itoh Score 4	Low strain of lesion
Itoh Score 5	Low strain of lesion and adjacent tissues

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According to ItohA et al, score 1, 2 and 3 are considered benign and score 4 and 5 are considered malignant.

We evaluated breast masses on SE using Siemens Acuson Antares ultrasound machine using linear L14-5 probe and we have now experience of eight years on this ultrasound machine. We faced initially problem in using SE due to learning curve and due to error of applying too much compressive force manually. But, slowly we have learnt this technique and now, we try to apply as less compressive force as possible. We have realized that SE technique is not good for masses present near chest wall and on skin surface. But, this technique has definitely increased our confidence in characterizing breast masses according to BIRADS based on grayscale, colour Doppler and SE. SE can't be used in following indications: diffuse breast lesions, breast implants, hematomas and postoperative changes.

On literature review, we have learnt that false positivity and false negativity can be seen on SE in following conditions[6,7] :

False Positivity	False Negativity
Complex Fibroadenomas	Lymphoma
Scarring	Invasive Lobular Carcinoma
Fibrosis	Ductal Carcinoma in situ (DCIS)
	Mucinous Carcinoma
	Necrotic tumors

Shear Wave Elastography (SWE)

In SWE, breast masses are subjected to compressive force by push pulses generated by ultrasound transducer using Acoustic Radiation Force Impulse (ARFI) technique[8,9]. As push pulses are generated by ultrasound transducer, this technique is more reliable and free from limitations due to human subjective component. We evaluated breast masses on SWE using Siemens Acuson S2000 ultrasound machine and we have now experience of three years on this ultrasound machine. On S2000 ultrasound machine, three different techniques/applications are available for SWE[10,11,12,13,14,15] :

1. Virtual Touch Imaging (VTI)

2. Virtual Touch Quantification (VTQ)

3. Virtual Touch Imaging and Quantification (VTIQ)

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For SWE, transducer is applied very lightly with generous amount of contact jelly. The transducer is usually placed perpendicular to chest wall and breast mass. Images and measurements are obtained after the best still and noncompressed position is obtained. Normal breast is usually taken as reference.

1.   In VTI, Elastographic image is obtained and compared with grey scale. Malignant masses are seen as dark region whereas benign masses are seen as bright region on Elastographic image. Largest diameter on Elastographic image is compared with largest diameter on grayscale. If this ratio is 1 or more, then mass is considered malignant. We found VTI to be useful for differentiating benign from malignant masses.

2.   In VTQ, greyscale Elastographic image is obtained. Region of Interest (ROI) can be placed within breast lesion and Quantitative shear wave velocity measurements can be recorded. These measurements are in metre per second (m/s) or kilopascal (kPa) depending on type of machine. In Siemens Acuson S2000, VTQ measurements are recorded in m/s and possible measurements are between 0 to 9 m/s. In cyst, shear waves can't propagate and hence measurements are recorded as X.XX. In most of malignant masses, shear wave velocity is more than 9 m/s and hence measurements are recorded as X.XX. Small breast lesions (less than 5 mm) couldn't be evaluated properly as rectangular ROI box is fixed (5 x 6 mm) and takes into account breast parenchyma adjoining breast lesion into shear wave velocity measurement. Our is a Tertiary care Oncology Institute and most of malignant breast masses came to us at late stage. Shear wave velocity measurement in most of malignant breast masses at our Institute was more than 9m/s and this was seen on Ultrasound Elastography as X.XX.

3.   In VTIQ, we first obtain Elastography image to see quality of image. If most of the breast lesion is showing high quality as compared with adjoining quality scale, then only we can obtain VTIQ measurement using ROI. ROI in VTIQ can be user defined and can be reduced to smallest possible size of 1 x 1mm. Quality is poor in calcified, necrotic and cystic areas and hence while taking VTIQ measurements, these areas should be avoided. If high quality Elastography measurements can't be obtained even after repeated attempts, then VTIQ shouldn't be used for breast leasion characterization. In Siemens Acuson S2000, VTIQ measurements were recorded in m/s and possible measurements were between 0 to 9 m/s. We used maximum shear wave velocity cut off of 4.5 m/s to differentiate malignant from benign breast masses. We found VTIQ to be more useful as compared to VTQ and VTI, as we were

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able to obtain reproducible quantitative shear wave velocity measurement in most of breast lesions[30].

We realized that SWE technique is not good for masses present near chest wall and on skin surface. But, this technique has definitely increased our confidence in characterizing breast masses according to BIRADS based on grey scale, colour Doppler and SWE (both quantitatively and qualitatively). Moreover, SWE being operator independent technique, is reproducible[16,17, 18].

DISCUSSION

Main role of Breast Elastography is in characterization of lesions in BIRDS 3 and 4 category and in taking management decisions: 1. Follow up of lesions or 2.FNAC/Biopsy of lesions. Elastography has the potential to reduce significantly biopsies in benign breast lesions[19,20,21]. We were able to upgrade many breast lesions from BIRADS category 3 to BIRADS category 4 using Elastography and these lesions were biopsied. Few lesions in BIRADS category 4 were downgraded to BIRADS category 3 and biopsy was avoided in these patients[22,23,24]. But, we didn't avoided breast biopsy in cases where there was high index of suspicion and ultrasound Elastography results were equivocally in favour of benign lesion.

Breast Elastography velocity measurement depends on various factors including breast thickness, compression applied, lesion size, depth of lesion, histologic profile and quality of Elastography image generated[25,26,27]. Hence, while using breast ultrasound Elastography, we should be very careful in applying as little compression as possible, with copious amount of contact jelly. We found that SWE can be used effectively for breast masses until depth of 5 cm from skin surface.

In Siemens S2000 SWE, a linear L9-5 probe is equipped with the ability to generate a low frequency longitudinal push pulse, which causes minimal localized tissue displacement and this can be tracked by a detection pulse[28,29]. The stiffer the breast tissue, the faster the shear wave propagates. This tissue compression is automated in SWE, examiner independent technique and reproducible. SWE can also be used to characterize breast lesions which can't be evaluated by SE. Yoon JH, et al concluded that a larger lesion size and increased breast thickness were correlated with a higher false positive rate, and a smaller size and deeper lesion were correlated with a higher false negative rate[30].

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Different investigators have proposed cut off value varying from 2.89 m/s to 5.2 m/s for differentiating benign from malignant breast lesions[31,32,33,34,35,36,37]. We used maximum SWE velocity cut off value of 4.5 m/s in VTIQ for differentiating benign from malignant breast lesions.

The quantitative shear wave velocity measurement in m/s and kPa showed good correlation and diagnostic performance in study by Youk JH, et al[37]. Chong JM, et al[38] concluded that the diagnostic performance of shear wave and strain elastography is similar. We obtained SWE on one view only and this can be one of limiting factor. Lee SH, et al concluded that two view SWE was better than one view SWE, when combined with B mode ultrasound[39].

Elasticity assessment has been included in Associated features category of Ultrasound Section of BIRADS fifth edition. It is hoped that with time, more robust data will emerge highlighting importance of Elastography in evaluation of breast lesions and then, Elastography will find mention as one of main feature in BIRADS assessment.

CONCLUSION

Breast Elastography is a useful technique which can reduce the need for biopsy in patients with low risk lesions. We hereby advocate that either Elastographytechnique: SE or SWE, can improve overall diagnostic performance in the differentiation of benign and malignant breast lesions, when combined with B mode ultrasound. Moreover, this requires only additional 5 minutes to study and same 9L4 linear probe can be used to characterize breast lesions.

Positive or negative Elastography results acquired on either SE or SWE can influence the BIRADS category of a breast mass, specially in BIRADS category 3/4a/4b. If equivocal Elastography results are obtained, either due to poor quality of images or other factors; then decision should be made based only on Greyscale and Doppler assessment[40].

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LEGENDS FOR FIGURES

1. Figure 1 :A 39 year old woman with breast cyst. Three layered colour pattern on Elastography image typical of a cyst.

2. Figure 2 : A 27 year old woman with fibrocystic myopathy Normal colour pattern with Itoh elasticity score of 1 (Normal Strain) suggestive of benign lesion.

3. Figure 3: A 32 year old woman with Fibroadenoma. Mosaic colour pattern with Itoh elasticity score of 2 (Strain over most of the lesion).

4. Figure 4: A 45 year old woman with Fibroadenoma. Strain at the periphery with Itoh elasticity score of 3.

5. Figure 5: A 60 year old woman with invasive ductal carcinoma. Entire lesion is red on Elastography image with Itoh elasticity score of 4 (No Strain over entire lesion).

6. Figure 6: A 44 year old woman with invasive ductal carcinoma. The lesion appears larger in size and red in colour on Elastography image because of local infiltration and desmoplastic reaction. Itoh score of 5 (No strain over entire lesion and surrounding parenchyma).
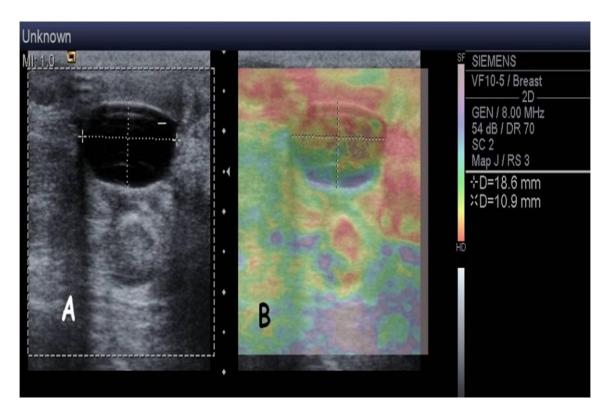
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7. Figure 7: A 38 year old woman with elastography score of 2, but pathological diagnosis was invasive ductal carcinoma (False negative case).

8. Figure 8: 29 year female with breast cyst. (8a) Greyscale image. (8b) Low quality factor due to shear wave not propagated through cyst. (8c) VTIQ Elastography image shows velocity can't be measured in breast cyst. (8d) VTQ Elastography image shows velocity measurement as X.XX m/s.

9. Figure 9: 42 year female with breast lipoma. (9a) Greyscale image showing echogenic lipoma. (9b) High quality factor seen as green colour covering entire lesion. (9c) VTIQ image shows maximum velocity measurement as 1.94 m/s.

10. Figure 10: 45 year female with fibroadenoma. (10a) Greyscale image. (10b) High quality factor seen as green colour covering entire lesion. (10c) VTIQ image shows maximum velocity measurement as 3.66 m/s.

11. Figure 11: 65 year female with invasive duct carcinoma. (11a) Greyscale image. (11b) VTQ Elastography image shows velocity measurement as X.XX m/s. (11c) Doppler image showing increased vascularity in superior part of lesion. (11d) VTIQ image shows maximum velocity measurement as 8.86 m/s.

12. Figure 12: 80 year female with adenocarcinoma with mucin production. (12a) Greyscale image. (12b) VTQ Elastography image shows velocity measurement as X.XX m/s. (12c) VTIQ image shows maximum velocity measurement as 8.38 m/s. (12d) Doppler image showing increased vascularity in peripheral and inferior part of lesion.

13. Figure 13: 40 year female with Recurrent Phylloides tumor (malignant). (13a) Greyscale image. (13b) VTQ Elastography image shows velocity measurement as X.XX m/s. (13c) VTIQ image shows maximum velocity measurement as 5.38 m/s.

14. Figure 14: 58 year female with Infiltrating ductal carcinoma. (14a) Greyscale image. (14b) VTI Elastography image shows dark lesion with maximum diameter more on elastography image as compared to maximum diameter on grey scale image. (14c) VTQ Elastography image shows velocity measurement as X.XX m/s. (14d) VTIQ image shows maximum velocity measurement as 6.38 m/s.

15. Figure 15: 50 year female with Breast abscess. (15a) Greyscale image. (15b) VTI Elastography image shows bright lesion with maximum diameter less on elastography image
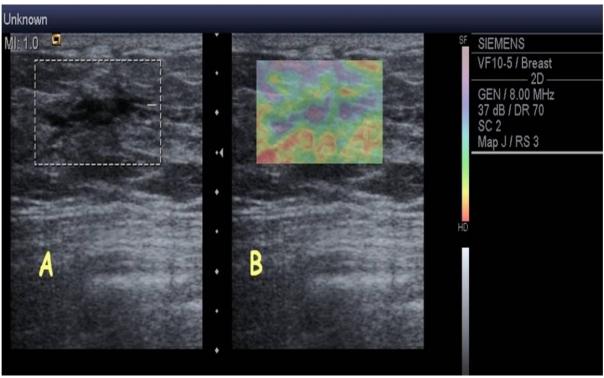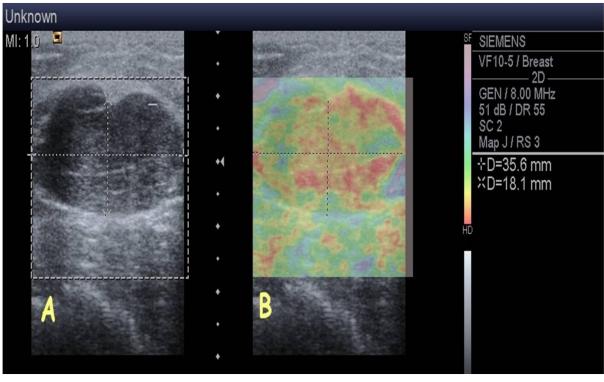
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as compared to maximum diameter on grey scale image. (15c) VTIQ image shows maximum velocity measurement as 8.43 m/s in perileshional area. (15d) Doppler image showing increased vascularity in peripheral part of lesion and perilesional area. (15e)VTQ Elastography image shows velocity measurement as 0.77 m/s.

16. Figure 16 : 58 year female with Calcified fibroadenoma. (16a) Greyscale image. (16b) VTI Elastography image shows dark lesion with maximum diameter less on elastography image as compared to maximum diameter on grey scale image. (16c) High quality factor seen as green colour covering entire lesion. (16d) VTIQ image shows maximum velocity can't be measured due to calcified region infibroadenoma.

17. Figure 17: 40 year female with High Grade Ductal carcinoma in situ. (17a) Greyscale image. (17b) VTI Elastography image shows dark lesion with maximum diameter more on elastography image as compared to maximum diameter on grey scale image. (17c) VTQ Elastography image shows velocity measurement as X.XX m/s. (17d) VTIQ image shows maximum velocity as 7.12 m/s. (17e) Doppler image showing increased vascularity in peripheral part of lesion and this area is corresponding to high velocity on VTIQ.

18. Figure 18 : 47 year female with Breast abscess and reactive axillary lymph node. (18a) Grey scale image of breast abscess. (18b) High quality factor seen as green colour covering entire lesion. (18c) VTIQ image shows maximum velocity measurement as 8.89 m/s. (18d) Grey scale image of reactive axillary lymph node.
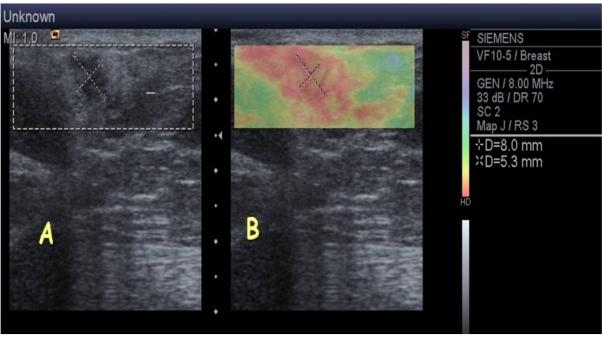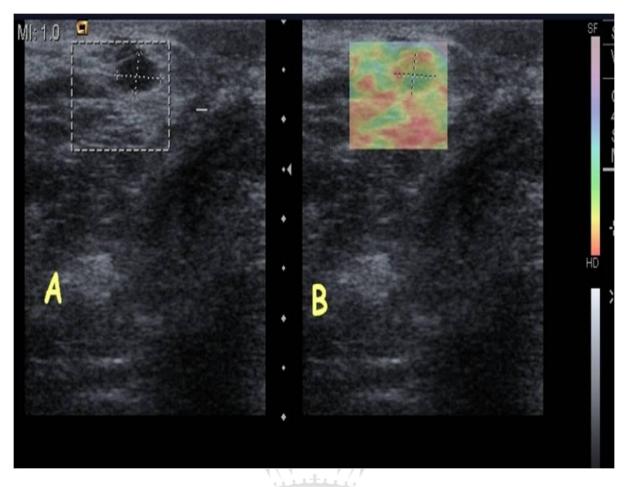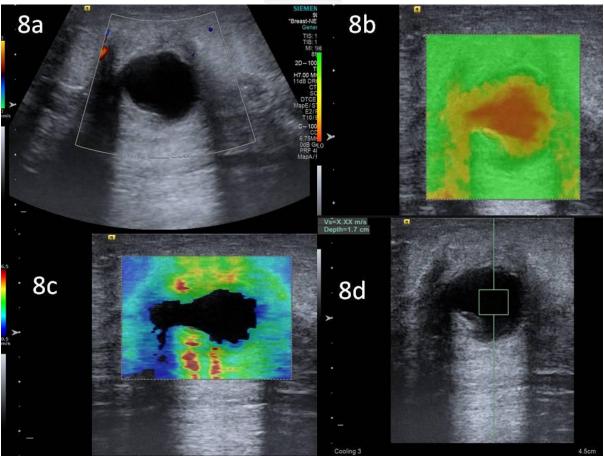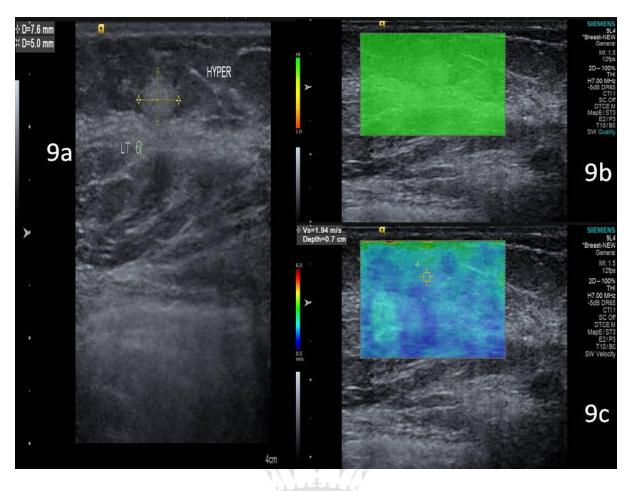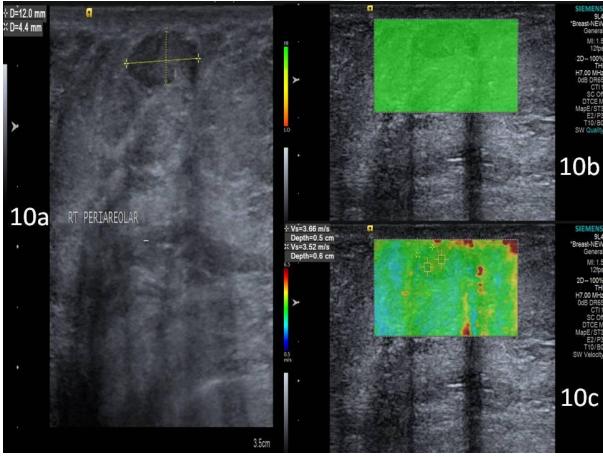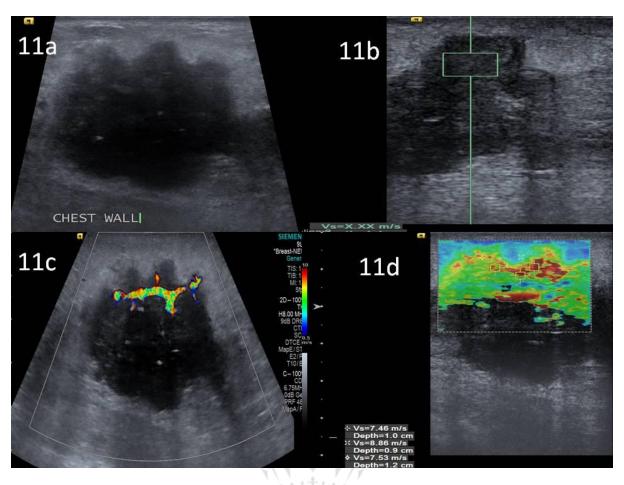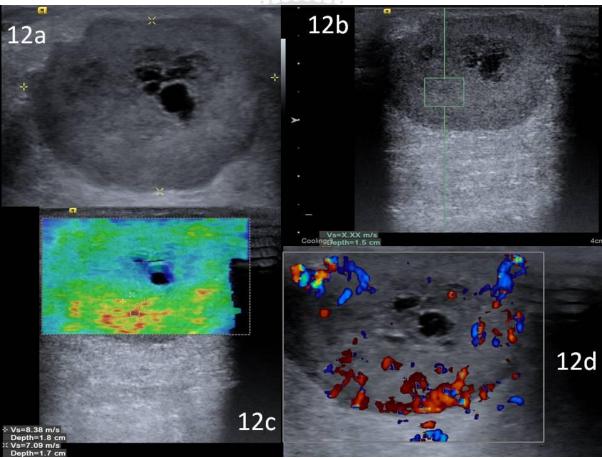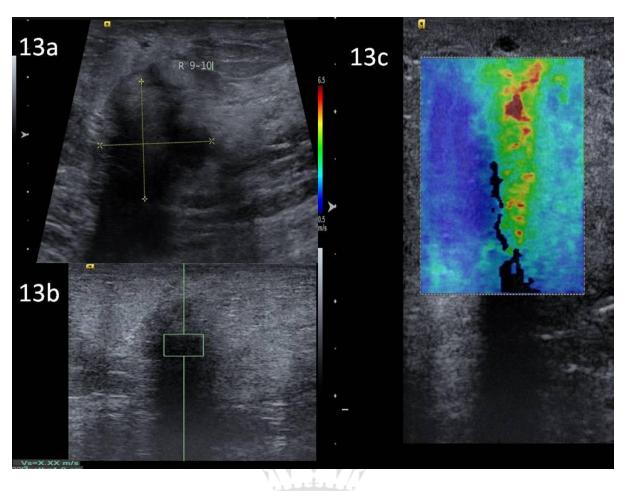
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