BREAST LESIONS: EVALUATION WITH ELASTOGRAPHY

Directed by DR M Jafari MD radiologist

Faculty member of IUMS

BI-RADS ASSESSMENT

- To **downgrade** the BI-RADS category in lesions with an absence of the SWE feature and **upgrade** the BI-RADS category in lesions with the presence of the SWE feature. However, category 3 lesions would not be downgraded, and category 5 lesions would not be upgraded.

BI-RADS ASSESSMENT

- The BI-RADS assessment category would be upgraded when any of the SWE features were suspicious for malignancy, while the category would be downgraded when no suspicious features were present at SWE.

ELASTOGRAPHY

- Elastography is used to characterize a lesion that **has already been detected in B mode**. It is a **characterization tool**, **not a detection tool.**

ELASTOGRAPHY

- With the first ultrasound machines equipped with elastography modules, **small regular pressure movements** on the probe were mandatory in order to obtain an elastogram whereas actually, **with new machines, sensitivity of software to the movement is so high that breath alone** is sufficient to create an image Thus, technical procedure is easier to perform and less operator-dependent.

ELASTOGRAPHY

- The image generated is an elastogram which may be displayed differently according to the manufacturer, either as a **colour image** or as a **black and white elastogram with differences in size and contours** in comparison with B mode image, or with **an elasticity measurement in speed level (ARFI, Siemens®)** or in **elasticity in kPa (Aixplorer, SuperSonic Imagine®)**

ELASTOGRAPHY

- Elastography is usually performed with the **same superficial ultrasound probe** that is used for B mode: with some companies, breast elastography (**10 MHz to 15 MHz**) **cannot be used with very high frequencies**, and **superficial probes with lower frequencies are then required.**

FREE-HAND TECHNIQUE

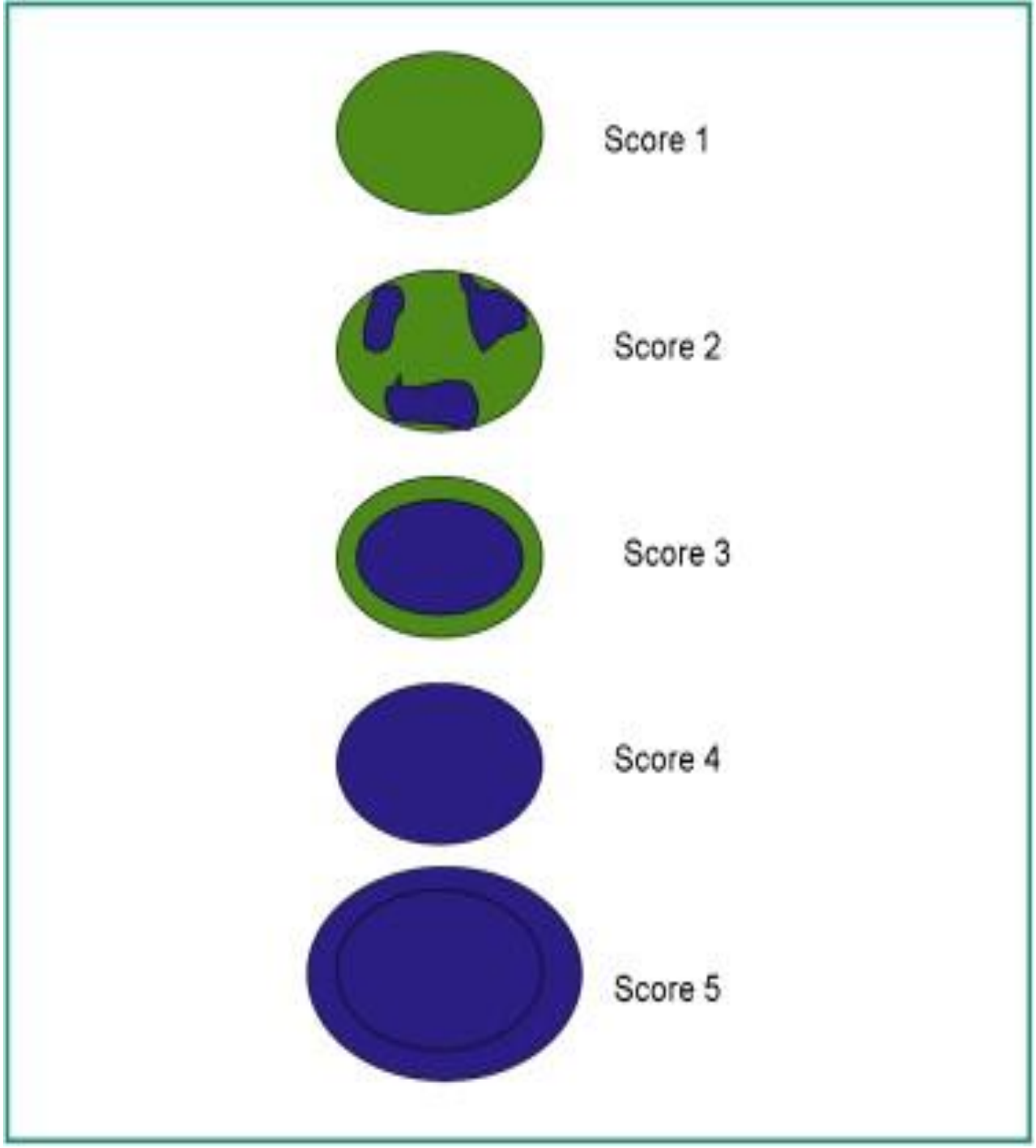
- After a short learning time, the technique is fast and easy to use. The cost of equipment is usually slightly **reduced** in comparison with shear wave technique (SWE).
- Its main disadvantage is that it is **relatively operator-dependent**, particularly in terms of the **pressure** applied to the probe and large variations can be obtained in images and values.
- Some manufacturers provide **quality scales** which makes **more reliable to establish** whether or not the acquisition has been correctly obtained.

SHEAR WAVE ELASTOGRAPHY

- This more **recent** mode is **available** in last generation of ultrasound machines, with also high quality of B mode ultrasound.
- Shear wave elastography (SWE) technique is classically **less operator-dependent**, although some degree of variability may occur **if too much pressure is applied on the probe** (elasticity values of kPa or shear wave measurement velocities can be artificially increased). The equipment is usually more expensive, and two different ultrasound probes are required, a very high frequency probe to obtain high resolution superficial ultrasound images and a lower frequency ultrasound probe used to obtain shear wave measurement.

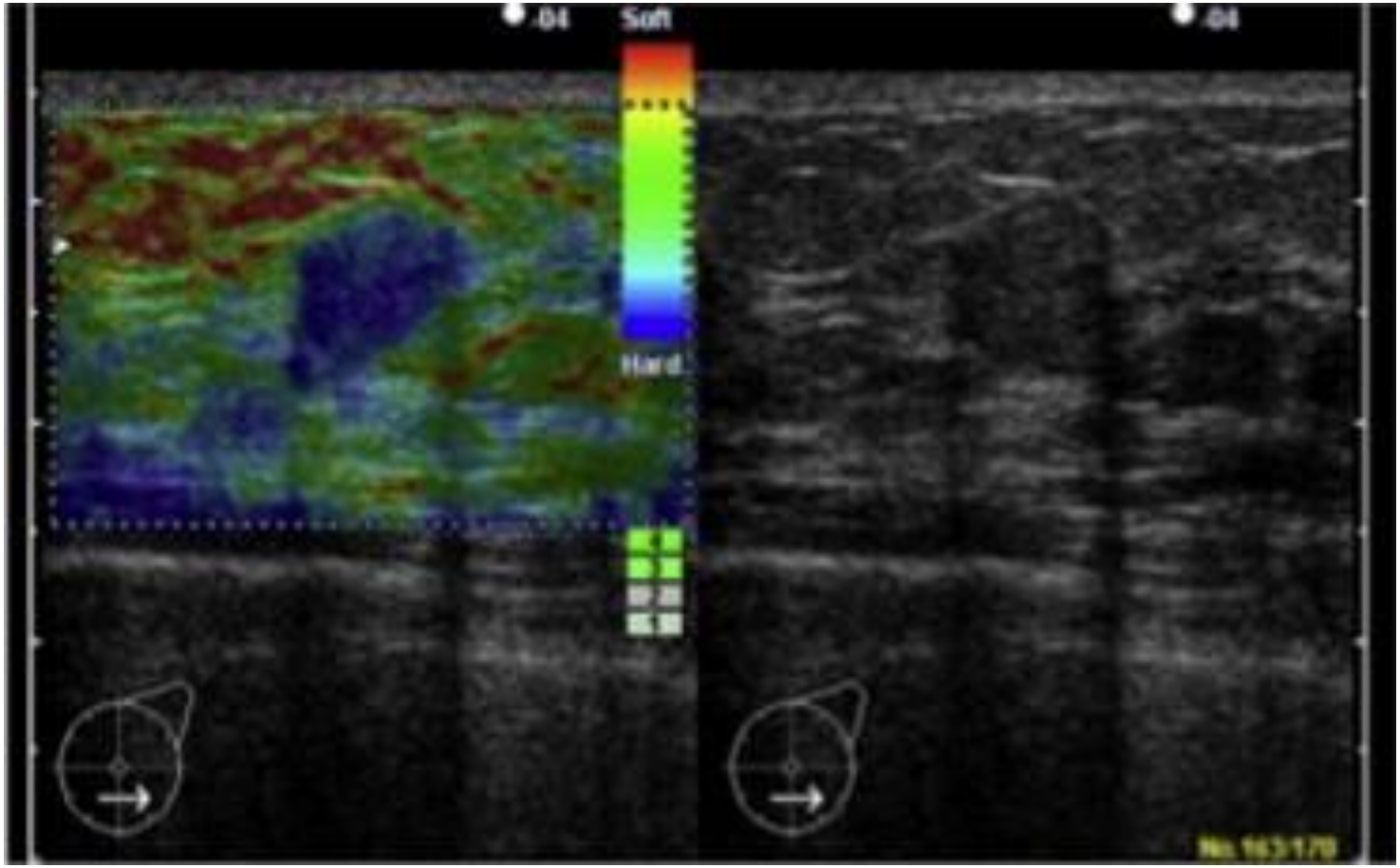
INTERPRETATIONS BASIS

- Interpretation varies according to the manufacturer. Elastogram may be either a **colour map, a black and white image** where contours and differences in size between B mode/ultrasound can be measured, **time curve in elasticity**, or an image on which the regions of interest **(ROI)** can be set in order to calculate relative **differences in elasticity with the surrounding tissue.**
- Elastography is now increasingly used to **improve the differential diagnosis of breast lesions and will affect the new BI-RADS breast lesion ultrasound classifications .**

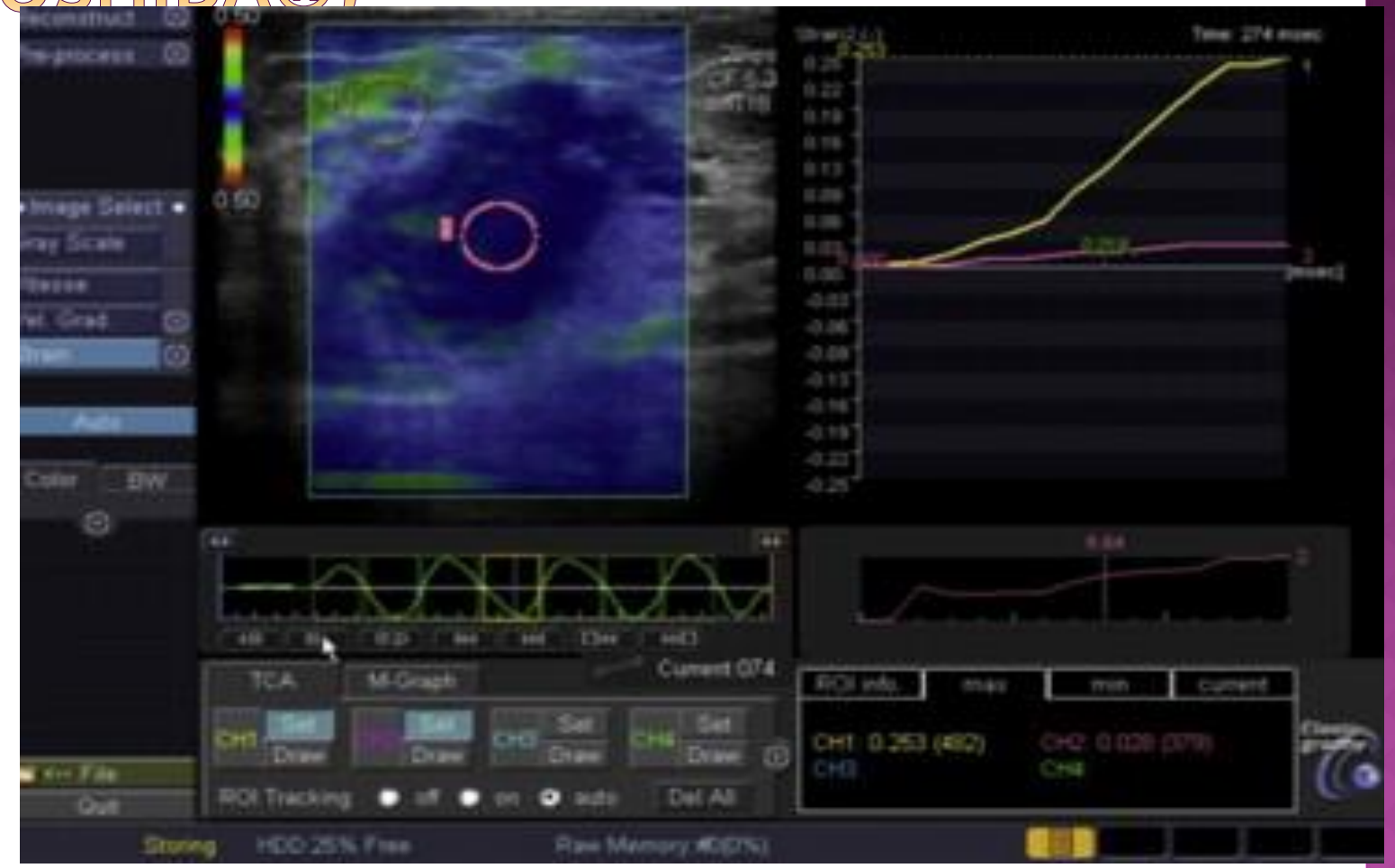

Score 1
Score 2
Score 3
Score 4
Score 5

- Hitachi® models produce a **colour elastogram**. Itoh et al. have proposed an elasticity score ,which has been validated in large series of biopsied breast lesions and compared to the BI-RADS classification of ACR for breast lesions. In order to categorize these images, Itoh et al. assessed the lesion colour scale both in the hypoechoic lesion and in the adjacent tissue. A 5-point **elasticity score** was joined for each image. A score 1 represents an entirely green lesion with the same elasticity throughout the lesion, a score 2 represents a lesion of which the greater part can be deformed although it may also contain **non-deformable areas** (green and blue mosaic), a score 3 corresponds to high elasticity level in the periphery of the lesion (green) whereas the centre of the lesion is blue, a score 4 indicates no deformability throughout the lesion (entire lesion is blue although the adjacent tissue is not affected) and a score 5 indicates no deformation throughout the hypoechoic lesion or the adjacent tissue (**lesion and adjacent tissue are blue**). The risk of malignancy increases from **1 (benign lesion) to 5 (malignant lesion)**

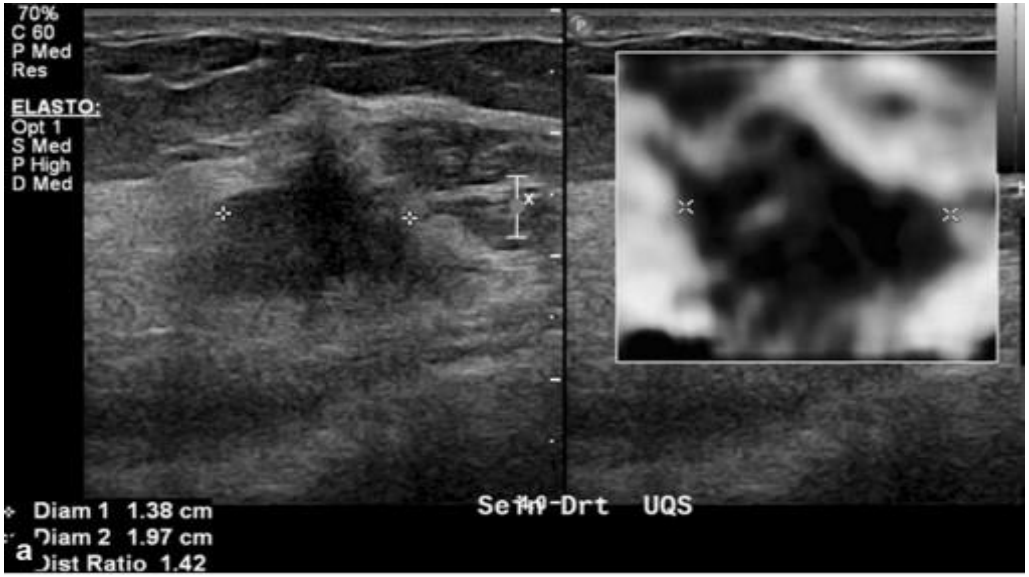
FREE-HAND ELASTOGRAPHY AND B MODE ULTRASOUND (HITACHI®).

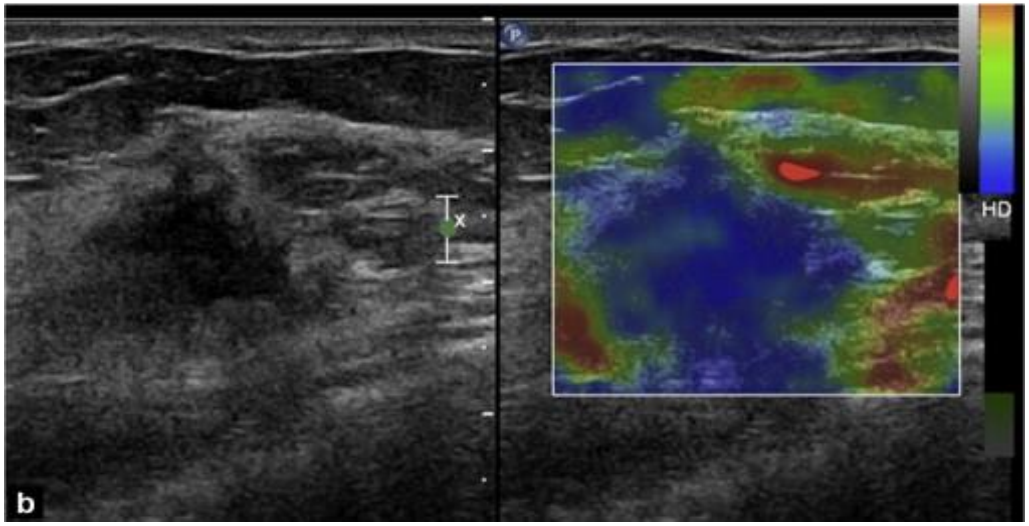


FREE-HAND ELASTOGRAPHY (TOSHIBA®)

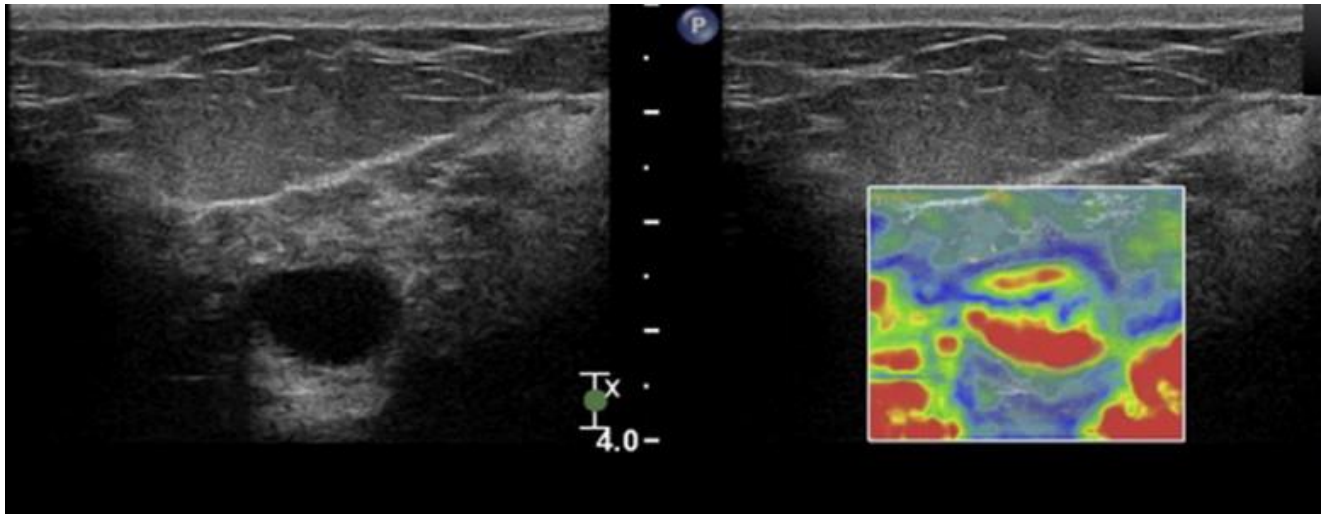


PHILIPS®, ELASTOGRAMS



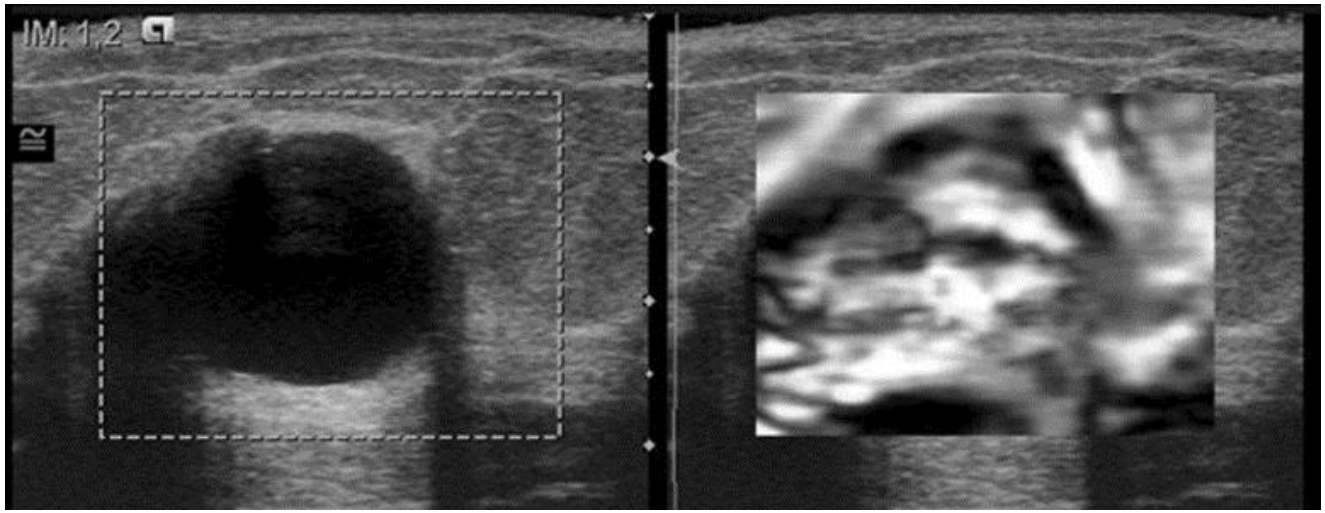


FREE-HAND ELASTOGRAPHY, COLOUR MODE (PHILIPS®).



- Malignant lesions are **usually larger in size than benign ones (usually more than 1.5 times larger);** margins are irregular with **a hypoechoic centre**, whereas benign lesions are more likely seen with a hyperechoic centre.
- Cysts have a typical **“bull's eye” appearance** (small size, white centre, peripheral black circle) .
- Strain level can also be quantified with an ROI positioned in the lesion and the other in the adjacent normal tissue at the same depth: **the risk of malignancy increases with increasing ratio.**

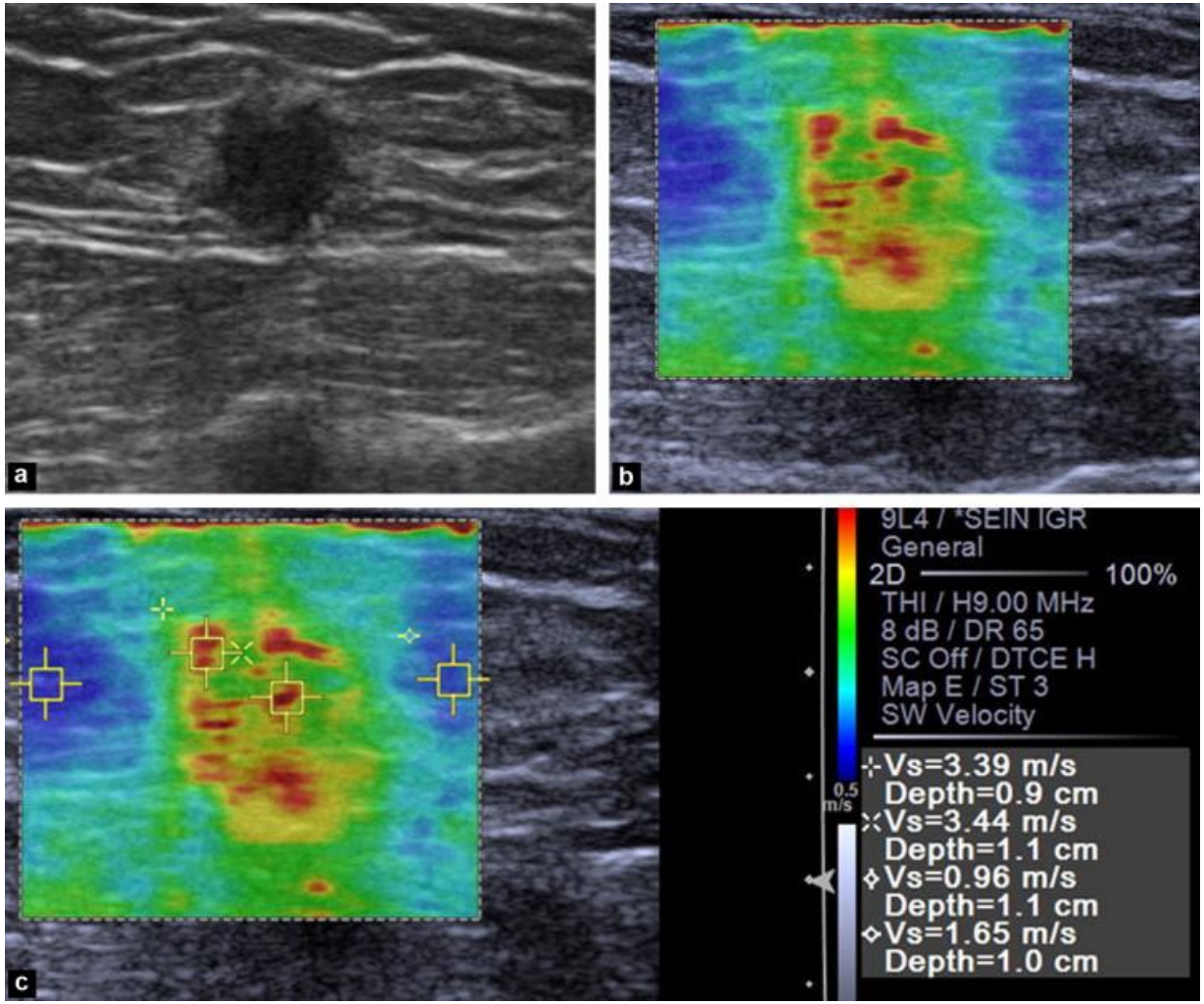
SIEMENS® FREE-HAND ELASTOGRAPHY



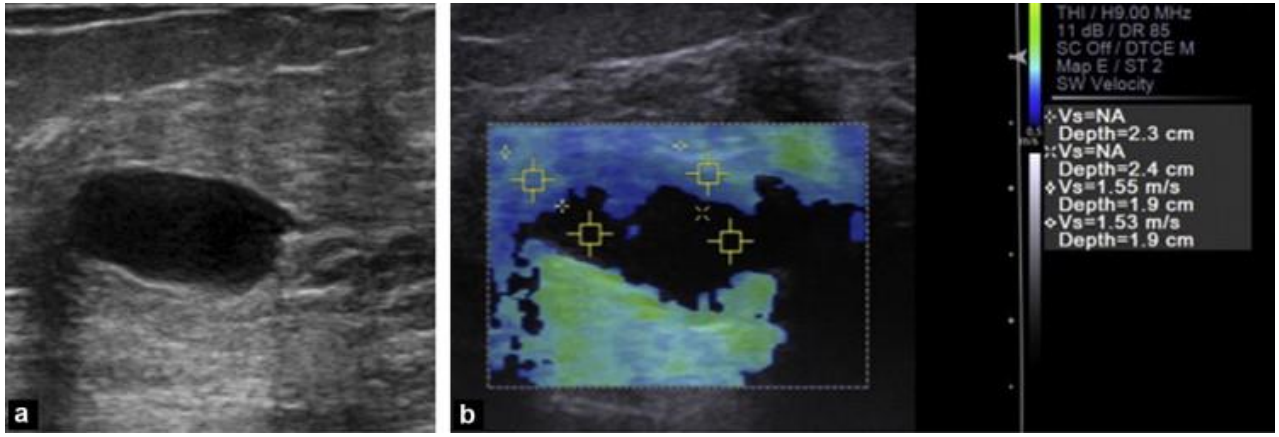
ACOUSTIC RADIATION FORCE IMPULSE (ARFI) MODE (SIEMENS®)

- In shear wave elastography mode (**ARFI**), three modes are available: a **colour map** can be obtained, or **velocity measurements** may be recorded in m/s or as a **colour velocity map**.
- According to data published in the literature and from our own personal experience, **velocities of over 2 m/s in the lesion are more often seen on malignant lesions.**

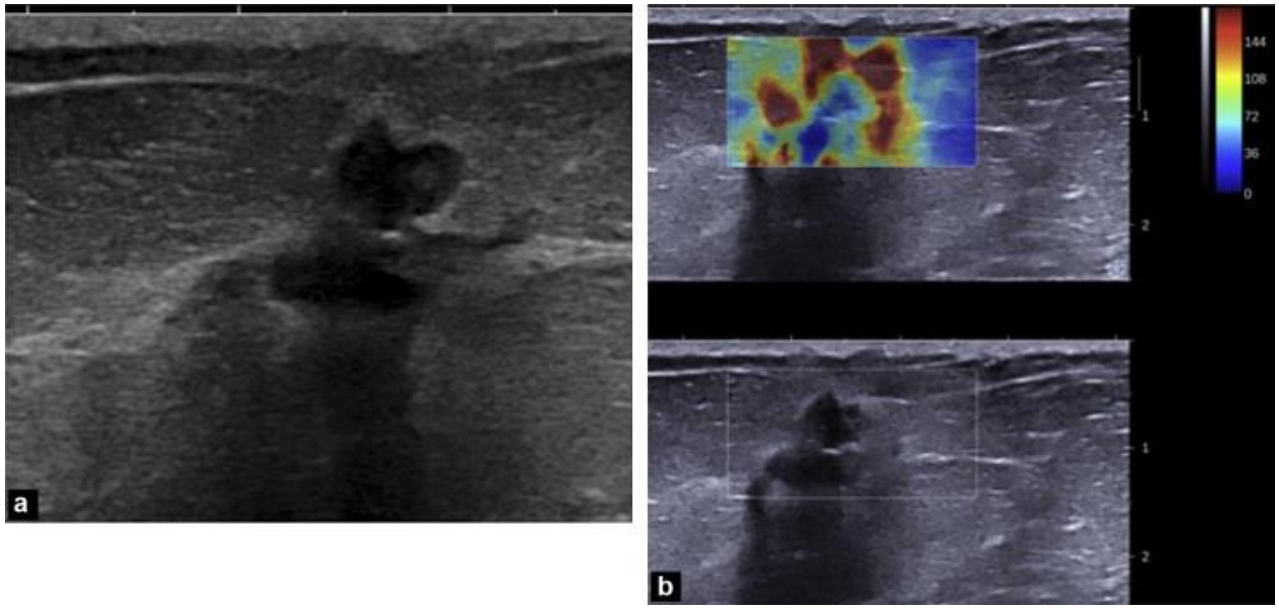
ACOUSTIC RADIATION FORCE IMPULSE MODE (SIEMENS®)



ACOUSTIC RADIATION FORCE IMPULSE MODE (SIEMENS®)



SUPERSONIC IMAGINE®



- On Supersonic Imagine® ultrasound machines, **elasticity is measured in kPa** and images are displayed on **a real time colour map** with an adjustable elasticity scale shown in kPa configured by **default for the breast at 180 kPa .**
- Once the acquisition has been performed (on a freeze image), the operator can measure **elasticity and elasticity ratios** on a region of interest. Several studies have shown variable elasticity threshold for benign or malignant lesions
- **values under 80 kPa associated with a GRAY SCALE BEINGN MORPHOLOGY arevaccurate parameters to assess a benign lesion.**
- **Malignant lesions usually have values over 120 kPa.**

FALSE POSITIVES

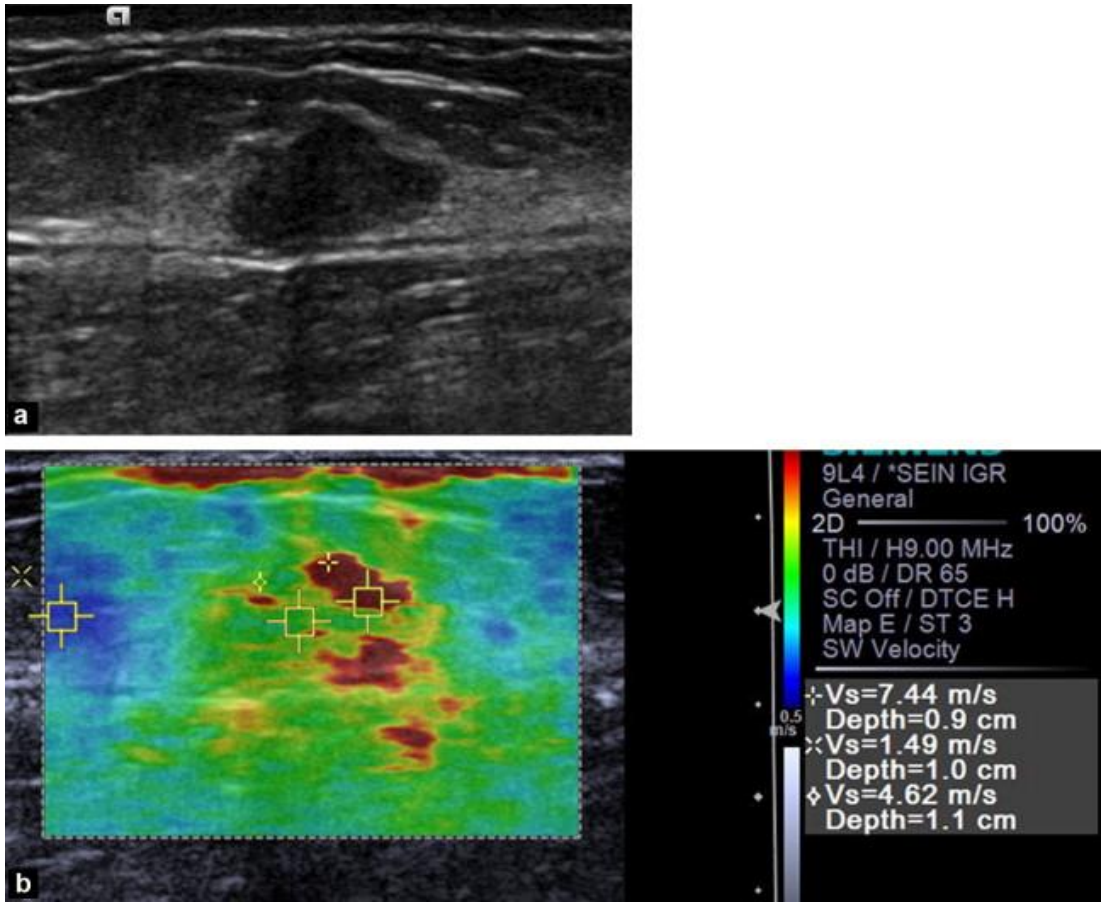
- Free-hand or shear wave elastography measures elasticity and strain of a lesion.
- **Breast cancers** are usually **poorly deformable** in comparison with benign lesions.
- Nevertheless, some **benign lesions** can be poorly deformable: such as **fibrous fibroadenoma** or **scars**. Thus elastography is not an accurate tool to evaluate **treated breasts**.
- **The presence of implants** can also change strain of breast tissue around the implant; lesion characterization may be impossible .

FALSE NEGATIVES

- Some breast cancers (such as **mucinous cancers, cancer with an inflammatory stroma or lesions less than 5 mm in size**) appear **highly deformable with pseudo-benign features on elastography**.
- However **morphology of these lesions is usually highly suspicious on B mode**; that may explain why both modes are then complementary.
- **Deep lesions (> 4-5 cm)** are also not always easily analysed with elastography, particularly with **free-hand mode** .
- Inconsistent results can also be obtained if the **density of the breast tissue is high**, and lead to false negative results

CHARACTERISATION OF BENIGN/MALIGNANT SOLID LESIONS

- **Many studies have shown** that the use of elastography parameters in adjunct to ultrasound parameters can **improve BI-RADS score** .
- On the other hand, it appears to be useful for malignant lesions presenting as benign lesions on B mode, **which appear poorly deformable on elastography**.
- **The best application seems to be applied to solid BI-RADS 3 or 4a lesions**.


a
b
9L4 / *SEIN IGR
General
2D
100%
THI / H9.00 MHz
0 dB / DR 65
SC Off / DTCE H
Map E / ST 3
SW Velocity
Vs=7.44 m/s
Depth=0.9 cm
Vs=1.49 m/s
Depth=1.0 cm
Vs=4.62 m/s
Depth=1.1 cm
0.5
m/s

FREE-HAND ELASTOGRAPHY

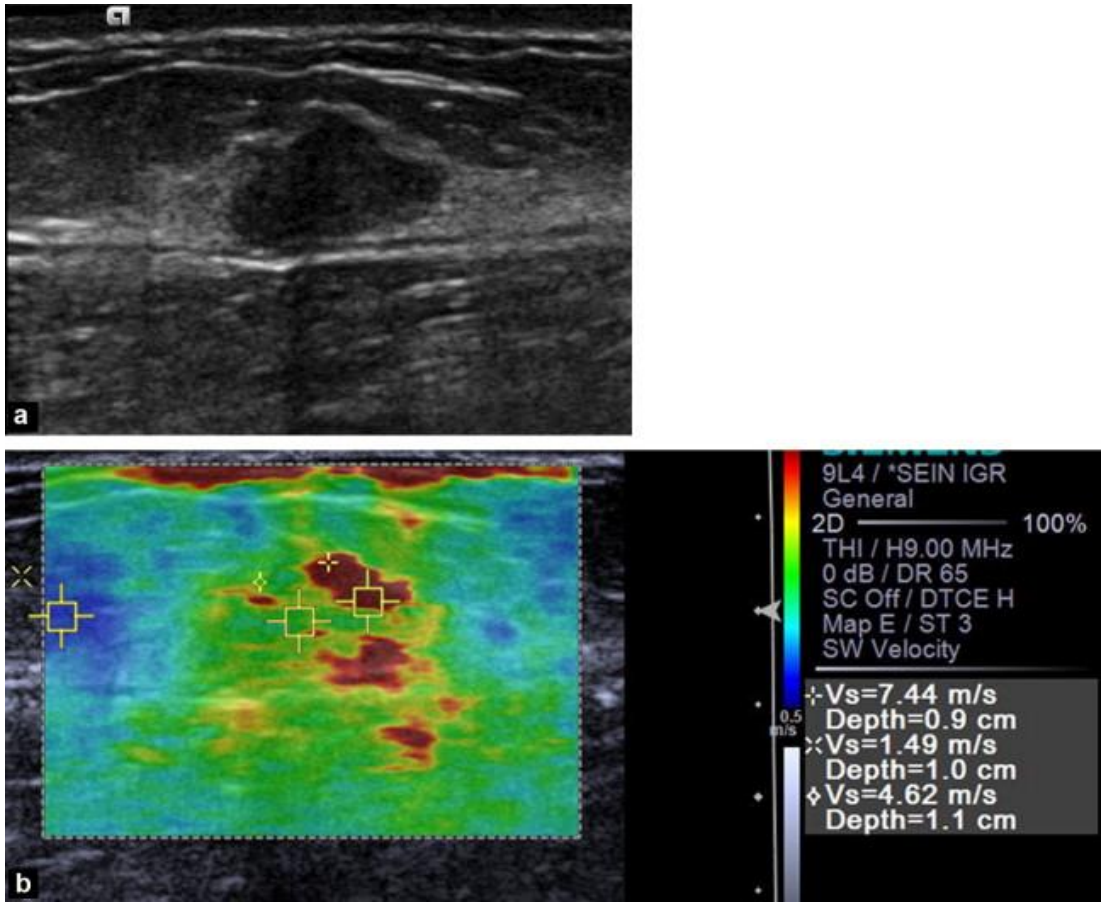
- A series of 370 patients with **lesions under 2 cm** (39% cancers) was studied using a free-hand elastography technique .
- BI-RADS score was improved with sensitivity and specificity increasing from 90.3% and 68.3% to 83.9% and 87.8% respectively when elastography was added.
- In another study of 193 lesions using a cut-off of 3:4 (Itoh classification), Schaefer et al. showed that sensitivity was **96.9% with a specificity of 76%** and recommended that static elastography should be used in addition to B mode ultrasound, as only two cancers in their study had a score of 1 (benign).
- Fischer et al., in another study of 200 histologically proven lesions (116 cancers), demonstrated that elasticity ratio was more sensitive and specific than B mode or even mammography with values of **95%** and 74% respectively with a cut-off of 2.27 .

- Another important point to differentiate benign/malignant lesions is that **cancers appear larger in elastography** than on B mode ultrasound .
- This may be due to the fact that local extension of the cancer is not always seen on B mode ultrasound but can be imaged by elastography.
- It is useful in free-hand elastography to measure the quantitative ratio between the lesion on B mode and on elastography.
- Barr et al. showed, in a multicentric study including 222 atypical malignant lesions and 413 benign lesions, that **a size ratio greater than 1** was found in 219 of 222 malignant lesions and that a size ratio less than 1 was found in 361 of 413 benign lesions, allowing a sensitivity of 98.6% and a specificity of 87.4% .
- **Elastography size appears also better correlated with histological size** .

- Elastography appearances of **cysts** in these studies were variable according the techniques used although free-hand elastography appeared to be accurate to confirm that an echoic lesion had a liquid content.

SHEAR WAVE ELASTOGRAPHY

- Like free-hand elastography, characterization of benign/malignant lesions **is improved for solid breast lesions** with shear wave elastography (SWE).
- Several studies have evaluated the input of SWE elastography to characterize breast lesions and have shown its **ability to reclassify masses which were initially classified as BI-RADS 3 and 4a.**
- In this multicentric study, SWE elastography improved specificity of conventional ultrasound from 61.1% to 78.5% in 650 lesions without significantly reducing specificity. These values were obtained with a **maximum shear wave velocity cut-off of 5 m/s (80 kPa) to improve specificity .**


a
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9L4 / *SEIN IGR
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100%
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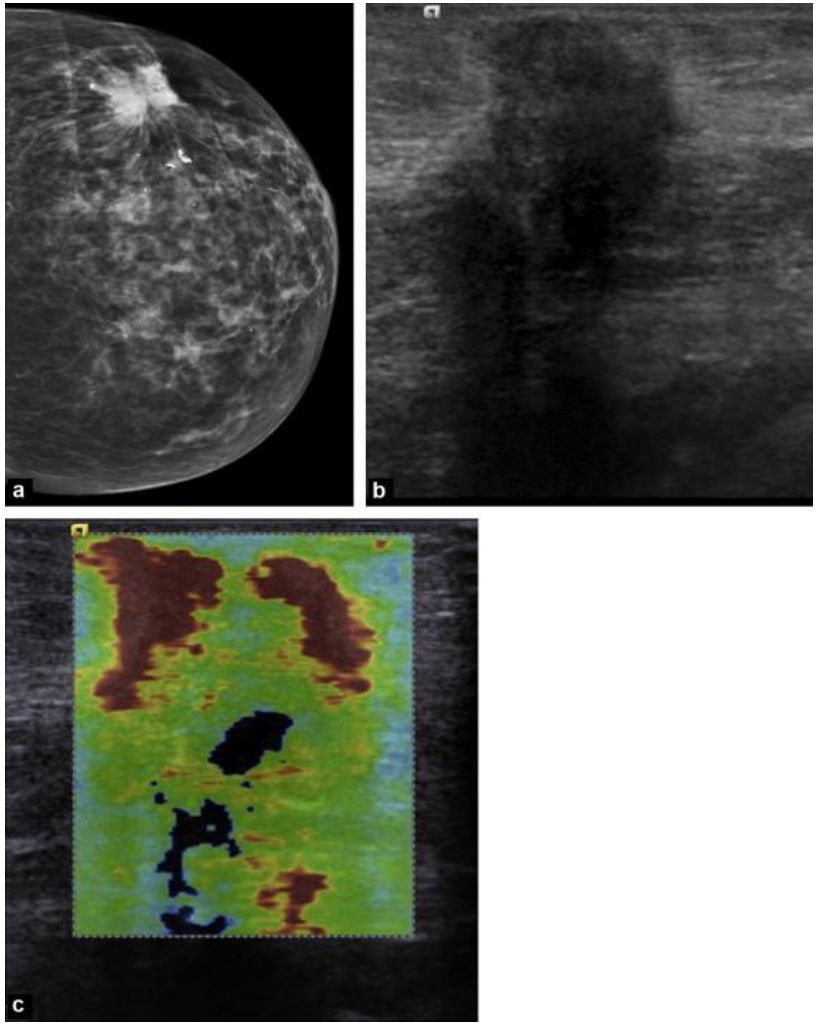
0 dB / DR 65
SC Off / DTCE H
Map E / ST 3
SW Velocity
Vs=7.44 m/s
Depth=0.9 cm
Vs=1.49 m/s
Depth=1.0 cm
Vs=4.62 m/s
Depth=1.1 cm
0.5
m/s

- In these different studies, strain values of malignant lesions were high (between 146 and 153 kPa) .
- **These different studies concluded that SWE elastography is highly reproducible to assess BI-RADS 3 lesions with benign features, with elasticity values less than or equal to 20 kPa.**
- On the other hand, it appears that the combination of the BI-RADS classification and elastography score offers greater sensitivity to diagnose malignancy .

- Anyway, **elastography** score **must not be used alone** independently of the BI-RADS score.
- Similar results were found with the other mode of SWE elastography, Acoustic Radiation Force Impulse (**ARFI**) mode.
- **A 3.6 m/s cut-off was found to differentiate benign from malignant** lesions in a series of 161 masses including 43 cancers, with **a sensitivity of 91% and a specificity of 80.6% .**
- In practice, the discrimination **cut-off between benign and malignant can vary from 2.20 m/s to 4.5 m/s** depending on the studies where this technique was evaluated .
- We have found that a **velocity score of 2.20 m/s** reaches a sensitivity of 94% with a specificity of 84% in a personal study of 112 lesions including 62 cancers.

- In both shear wave elastography techniques, **SWE and ARFI, elasticity sometimes cannot be calculated when deformation of a tissue is too low.**
- This may occur in large, **very rigid infiltrative cancers** .In this case, ultrasound beam cannot penetrate high attenuating areas such as the deepest part of scirrhous cancers. **Colours are not seen on SWE mode** or xxx value is displayed instead a register speed in m/s on ARFI mode. These features must not be misunderstood with low values seen on benign lesions. **The systems cannot measure elasticity values in lesions where the tissue does not vibrate enough or because the amplitude of the shear wave is too low and thus lost in the background noise**


a
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- Evans et al reported that some malignant breast lesions showed **typical peritumoral stiffness in the color elastic map**, and Tozaki and Fukuma (20) reported that a localized area of color, which represented **increased stiffness at the lesion margin**, was a sign of malignancy. Here, we call this finding the **“stiff rim” sign**.

- Similarly, **non-viscous cysts do not generate shear waves** and can appear as **black areas** in the hypoechoic area on B mode ultrasound. **When the cyst has a minimum level of viscosity, however, shear waves can be recorded with low values.**

ROLE OF ELASTOGRAPHY TO ASSESS MICROCALCIFICATIONS CLUSTERS

- Some publications reported that the different breast tissues have variable elasticity characteristics depending on their values of fat, gland and connective tissue and that it is possible to differentiate the intraductal or infiltrative malignant component of a malignant lesion .
- Cho et al. in a recent study assessed elasticity of microcalcifications clusters associated with hypoechoic lesions.
- **Benign lesions associated with microcalcifications were significantly more deformable than malignant lesions associated with microcalcifications.**
- **The technique used was however more sensitive than specific (97% versus 62%) and cannot therefore replace mammography or biopsy.**

ELASTOGRAPHY OF LYMPH NODES

- Metastatic axillary nodes appear to be more vascularized and less deformable than benign inflammatory lymph nodes .
- Choi et al. evaluated the input of elastography to differentiate benign from malignant lymph nodes in a series of 64 lymph nodes (33 reactive, 31 malignant) and showed that **elasticity score for malignant lymph nodes (average 3.1) was higher than for benign lymph nodes (average 2.2; $P < 0.0001$).** With an elasticity score of 2–3, sensitivity reaches 80.7% as specificity was 66.7%.
- Same results were found by Tourasse et al. in a population of 65 patients undergoing surgery for breast cancer, in whom 103 lymph nodes were examined by SWE elastography, as 81 lymph nodes were correlated histologically (70 normal, 11 malignant).
- **Elasticity values were significantly different between normal and metastatic lymph nodes ($P < 0.05$).** These studies, however, should be interpreted carefully as only a small number of lymph nodes were malignant; moreover, **no study has proved that elastography can confirm accurately a micrometastatic invasion.**

THANKS