



SOLICITED REVIEW / *Breast Imaging*

Breast sonoelastography: Now and in the future



B. Mesurolle^{a,*}, M. El Khoury^b, F. Chammings^c,
M. Zhang^d, S. Sun^d

^a Department of Radiology, centre république, Elsan, 99, avenue de la république, 63023 Clermont-Ferrand, France

^b Department of Radiology, Centre Hospitalier de l'Université de Montréal, Québec, Canada

^c Unité de radio-sénologie, department of radiology, institut Bergonié, 33000 Bordeaux, France

^d Breast Clinic, McGill University Health Center, Montreal, Québec, Canada

KEYWORDS

Breast sonoelastography;
Shear-wave elastography;
Strain elastography;
Breast ultrasound;
Breast cancer

Abstract

Purpose: The purpose of this study was to identify practice trends and opinions concerning breast sonoelastography in two different health care systems, one in Europe (France) and the other in North America (Province of Québec/Canada).

Materials and methods: We distributed an 11-item online survey among French and Canadian breast radiologists. The survey comprised of four sections: (i) personal practice characteristics, (ii) breast sonoelastography usage in daily practice and evaluation of its usefulness, (iii) limitations and roles of sonoelastography in their clinical practice, and (iv) types of elastographic technique and interpretation.

Results: We found that sonoelastography of the breast appears unpopular among Canadian radiologists, and poorly credible among French radiologists, who perceive it as an unreliable technique. To date, its real impact in clinical practice remains uncertain.

Conclusion: Continued learning and awareness of the indications, advantages and limitations of breast sonoelastography may motivate breast radiologists to adopt its use.

© 2019 Société française de radiologie. Published by Elsevier Masson SAS. All rights reserved.

Sonoelastography, a technique initiated in the 1980s, is an emerging ultrasound tool able to assess tissue deformability

by providing information on its elasticity [1,2]. The World Federation for Ultrasound in Medicine and Biology (WFUMB) guidelines state that “elastography should be used to characterize an abnormality identified on conventional B-mode imaging” [3]. Indeed, sonoelastography has the potential to complement the conventional greyscale and color breast

* Corresponding author.

E-mail address: bmesurolle@yahoo.fr (B. Mesurolle).

ultrasound to improve characterization of breast lesions, as cancerous lesions tend to be stiffer than benign lesions [3]. Two different techniques are used: compressive, or strain, elastography and shear-wave elastography [4].

Despite encouraging beginnings with convincing published results and although a variety of manufacturers have incorporated elastography into their ultrasound equipment, there is no certainty that this technique is widely implemented by breast radiologists in their daily practice [5–8]. Skepticism seems to slow its diffusion in daily and routine breast imaging activity, which in a way is not dissimilar to the beginnings of breast ultrasound [9].

The purpose of this study was to identify practice trends and opinions concerning breast sonoelastography in two different health care systems, one in Europe (France) and the other in North America (Province of Québec/Canada).

Material and methods

Study participants

From May to July 2018, a web-based survey was conducted with members of the Société d'Imagerie de la Femme (SIFEM, France), Société québécoise de radiologie (SQR, Québec, Canada) and the Canadian Society of Breast Imaging (CSBI, Canada) targeted to radiologists involved in breast imaging.

Survey tool

An 11-item questionnaire was designed in which respondents were asked to choose a single best response for each question. The survey was comprised of four sections: (i) personal practice characteristics (e.g. physician age and type of practice); (ii) breast sonoelastography usage in daily practice and evaluation of its usefulness; (iii) limitations and roles of sonoelastography in their clinical practice; (iv) types of elastographic technique and interpretation criteria used and manufacturing brands of the ultrasound apparatus.

The survey was sent via a cloud-based internet tool (SurveyMonkey). Radiologists were contacted and asked to voluntarily complete an anonymous survey within 4 weeks; a single follow-up e-mail was sent a few weeks later. Each completed survey response represented a unique radiologist.

Personal practice characteristics

Questions 1, 2, and 3 determined the practice setting of the respondents (academic, private, community, oncologic center-based, or other type), and their involvement in breast imaging, categorized as "the main activity", "a substantial part", "a limited part", or "none" of their clinical time.

Breast sonoelastography usage and opinion about its usefulness

Questions 4 and 5 determined the current practice regarding breast sonoelastography and evaluated the opinion of the respondents with respect to the usefulness of sonoelastography in their clinical practice.

Limitations of sonoelastography

Questions 5 and 6 determined the reasons behind limited use of sonoelastography by breast radiologists.

Roles of sonoelastography in breast imaging in daily practice

Question 7 determined the main indications of sonoelastography in daily practice.

Type of sonoelastography used and interpretation of elastographic images

Questions 8, 9, and 10 determined the specific technique (i.e., compressive, or strain, elastography and shear-wave elastography) and interpretation tools used by breast radiologists.

Results

Response rate

A total of 156/510 (30.6%) French radiologists responded to the survey as well as 74/231 (31.6%) from Québec and 16/58 (27.6%) from other Canadian provinces, resulting in a total response rate of 30.8% (246/799).

Survey results

Demographics and personal practice characteristics

The majority of participants were between 30–59 years of age, with the most common age bracket of 50–59 for France, Canada, and Québec. Most respondents from France work in a private clinic (50.6%), whereas most respondents from Canada work in a university hospital center (60.0%) and those from Québec work in a community hospital (46.0%). Most surveyed radiologists indicated breast imaging either as their main specialty or more than 50% of their practice (Table 1).

Breast sonoelastography usage and opinion about its usefulness

French radiologists use breast sonoelastography much more in their daily practices than their Canadian/Québec counterparts. Among French radiologists, 17.4% responded that they routinely use breast sonoelastography and 27.7% responded that they use it often. Among North American radiologists, 0% use breast sonoelastography routinely and 4.1–6.2% reported using it often. The majority of breast radiologists from Canada and Québec (68.8% and 82.2%, respectively) report that they never use the sonoelastography technique (Table 2).

Roles of sonoelastography in breast imaging in daily practice and limitations of sonoelastography

The top reasons listed for not using elastography was that it is an unreliable test (more commonly reported by French

Table 1 General information of the responders.

	France	Canada	Québec
<i>Age (years)</i>			
< 30	5.2% (8/155)	0% (0/16)	0% (0/74)
30–39	24.5% (38/155)	6.2% (1/16)	31.1% (23/74)
40–49	22.6% (35/155)	31.3% (5/16)	14.9% (11/74)
50–59	34.8% (54/155)	56.3% (9/16)	43.2% (32/74)
≥ 60	12.9% (20/155)	6.2% (1/16)	10.9% (8/74)
Skipped	1	0	0
<i>You are a radiologist working in:</i>			
University hospital	17.3% (27/156)	60% (9/15)	27% (20/74)
Private clinic	50.6% (79/156)	13.3% (2/15)	23% (17/74)
Community hospital	16.7% (26/156)	20% (3/15)	46% (34/74)
Cancer center	12.8% (20/156)	0% (0/15)	1.3% (1/74)
Other	0% (0/156)	6.7% (1/15)	2.7% (2/74)
Skipped	0	1	0
<i>Breast imaging is:</i>			
Your main specialty	57.4% (89/155)	25% (4/16)	14.9% (11/74)
> 50% of your practice	37.4% (58/155)	31.2% (5/16)	67.6% (50/74)
< 50% of your practice	3.2% (5/155)	43.8% (7/16)	5.4% (4/74)
0% of your activity	2% (3/155)	0% (0/16)	12.2% (9/74)
Skipped	1	0	0

Data are presented as percentage. Numbers in parentheses are proportions.

Table 2 Usage and opinion about usefulness of breast sonoelastography.

	France	Canada	Québec
<i>When do you use sonoelastography?</i>			
Never	29.7% (46/155)	68.8% (11/16)	82.2% (60/73)
Seldom	25.2% (39/155)	25% (4/16)	13.7% (10/73)
Often	27.7% (43/155)	6.2% (1/16)	4.1% (3/73)
Automatic	17.4% (27/155)	0% (0/16)	0% (0/73)
Skipped	1	0	1
<i>Your opinion about sonoelastography in your practice:</i>			
Useless	7.8% (12/154)	6.3% (1/16)	11.8% (8/68)
Rarely useful	31.8% (49/154)	50% (8/16)	44.1% (30/68)
Useful	48.7% (75/154)	43.7% (7/16)	42.7% (29/68)
Very useful	11.7% (18/154)	0% (0/16)	1.5% (1/68)
Skipped	2	0	6

Data are presented as percentage. Numbers in parentheses are proportions.

Table 3 Limitations of breast sonoelastography.

	France	Canada	Québec
<i>You seldom use sonoelastography because:</i>			
Unreliable test	46.7% (50/107)	60% (9/15)	22.5% (16/71)
Time-consuming test	24.3% (26/107)	6.7% (1/15)	11.3% (8/71)
Long learning curve	0% (0/107)	0% (0/15)	0% (0/71)
Unknown indications/interpretation	29% (31/107)	33.3% (5/15)	66.2% (47/71)
Skipped	49	1	3

Data are presented as percentage. Numbers in parentheses are proportions.

Table 4 Roles of breast sonoelastography.

	France	Canada	Québec
<i>You use sonoelastography in your daily practice because it mostly helps</i>			
Downgrading	14.2% (19/134)	25% (2/8)	27.9% (12/43)
Upgrading	28.4% (38/134)	12.5% (1/8)	27.9% (12/43)
Up and downgrading	48.5% (65/134)	37.5% (3/8)	27.9% (12/43)
Detection	9% (12/134)	25% (2/8)	16.3% (7/43)
Skipped	22	8	31

Data are presented as percentage. Numbers in parentheses are proportions.

Table 5 Type of sonoelastography technique (strain vs. shear-wave).

	France	Canada	Québec
<i>You mainly use:</i>			
Strain	15.1% (19/126)	66.7% (4/6)	29% (9/31)
Shear-wave	63.5% (80/126)	16.7% (1/6)	41.9% (13/31)
Both	7.9% (10/126)	16.7% (1/6)	9.7% (3/31)
Unaware	13.5% (17/126)	0% (0/6)	19.3% (6/31)
Skipped	30	10	43
<i>If you use strain elastography, your interpretation is based on:</i>			
Color map	67.9% (57/84)	80% (4/5)	52% (13/25)
Strain ratio	11.9% (10/84)	0% (0/5)	16% (4/25)
Both	20.2% (17/84)	20% (1/5)	32% (8/25)
Skipped	72	11	49
<i>If you use shear-wave elastography, your interpretation is based on:</i>			
Color map	62.2% (69/111)	50% (1/2)	61.6% (16/26)
kPa values	35.1% (39/111)	50% (1/2)	19.2% (5/26)
Strain ratio	2.7% (3/111)	50% (0/2)	19.2% (5/26)
Skipped	45	14	48

Data are presented as percentage. Numbers in parentheses are proportions.

and Canadian radiologists), not knowing the indications, or difficulty interpreting the results (top answer by radiologists from Québec) (Table 3). For those who used elastography for breast imaging interpretation, upgrading and downgrading lesions appeared to be the main purpose, and lesion detection was a secondary purpose (Table 4).

The brand of ultrasound machines also varied widely, with Toshiba (Canon) and Aixplorer mainly used in France, Toshiba (Canon) in Québec and the General Electric Healthcare in Canadian provinces other than Québec.

Type of sonoelastography used by breast radiologists and technique of interpretation of elastographic images

The specific type of sonoelastography used depended on the region. Radiologists from France and Québec use mainly shear-wave and color map; whereas the radiologists from other Canadian provinces use predominantly strain and color map (Table 5). For those who used shear-wave elastography, the interpretation is mainly based on the color map for all 3 groups of radiologists (50.0-62.2%).

More than half of the French radiologists (60.4%) rated sonoelastography as either useful or very useful, whereas

the majority of those from Canada and Québec rated it as useful (43.7% and 42.7%, respectively) and rarely useful (50.0% and 44.1%, respectively).

Discussion

Despite being the subject of abundant literature authored by eminent experts encourage radiologists to use sonoelastography in breast imaging [8], the feedback of breast radiologists regarding its use and impact in clinical practice has not been evaluated. This work describes the usage of this emerging and promising tool among specialized breast radiologists working in France, Québec, and Canada.

Sonoelastography in clinical practice: Where are we?

This survey achieved a response rate of nearly 30% in France, Québec, and Canada, which meets the reasonable expectations of an Internet survey, which usually achieve below 50% [10,11]. However, the small number of responses obtained from Canadian participants means that this subset of received results should be interpreted with caution

(CSBI was recently founded at the time the survey was initiated, which likely explains the relatively low number of respondents).

The type of work setting varied among the different geographical regions, as French radiologists are mostly settled in private practice. In comparison, radiologists from Canada are most often affiliated with a university or community hospital. These different types of working environments in Europe and North America could substantially affect the type of breast imaging practice.

Nonetheless, each region has access to similar equipment and literature. Despite the recent incorporation of qualitative sonoelasticity measurements (soft, intermediate or hard) of breast lesions as an associated finding in the 5th edition of the BI-RADS ultrasound lexicon, the adoption of sonoelasticity into the daily practices of the radiology community remains slow and somewhat geography-dependent [12]. Indeed, sonoelastography is definitively more unpopular amongst radiologists in Canada, since 69% of Canadian and 82% of Québécois radiologists reported never using sonoelastography compared to only 29% of French radiologists.

A different work organization and an old mistrust of breast ultrasound might partly explain reluctance of radiologists from Canada to use this technology. Indeed, in many North American institutions, breast ultrasound is considered a time-consuming and operator-dependent technique and is most often performed by specialized breast technologists under the supervision of breast radiologists. The known intra- and inter-operator variability of the technique limits its acceptance in clinical practice [13]. A radiologist supervising and interpreting images, e.g. sonoelastographic images, usually generated by another individual (breast technologist), would be more reluctant to use its results.

Breast sonoelastography usage and opinion regarding its usefulness and roles in daily practice

The results of the survey confirm an intuitive perception from radiologists using sonoelastography in their routine practice: there is a common reluctance, more so in Canada than in France, of routinely adopting sonoelastography in

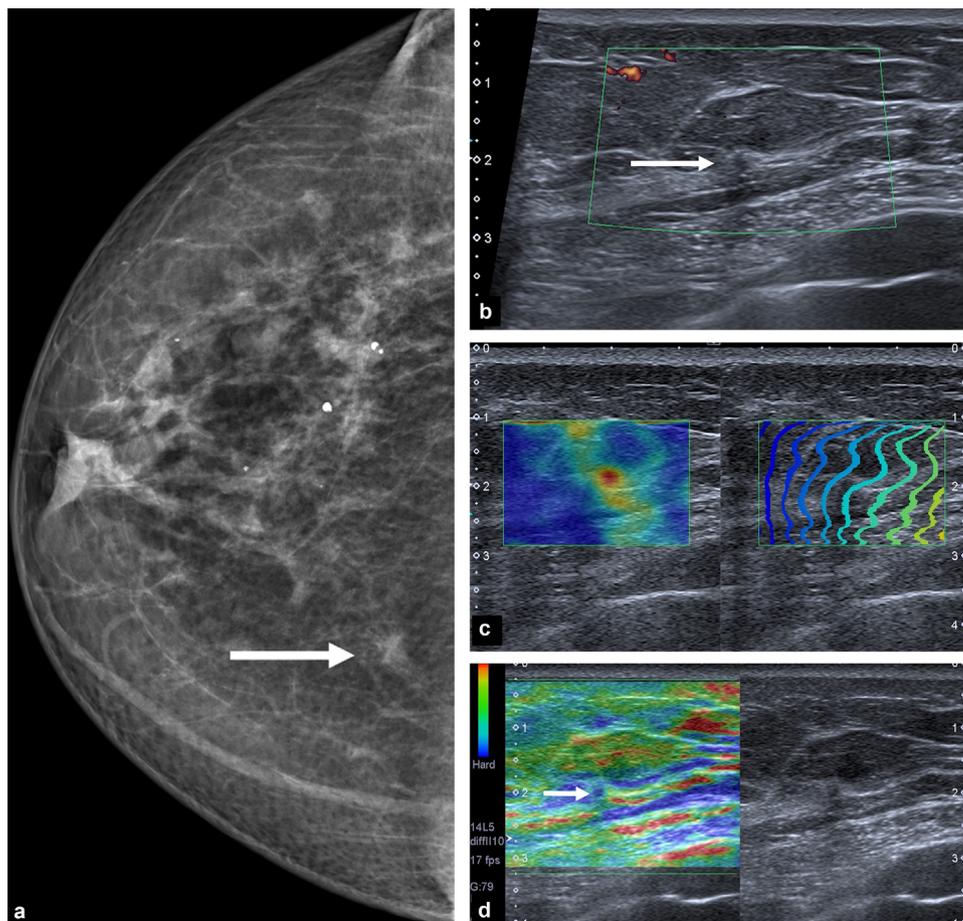


Figure 1. 65-year-old asymptomatic woman. (a): Screening mammogram (right cranio-caudal view) shows a 5 mm focal asymmetry in the medial aspect of the right breast (arrow), persisting on compression view (not shown). (b): Ultrasound correlation shows a deeply located, small, 4-mm subtle hypoechoic round mass (arrow), categorized as BIRADS IVC. (c): Mass and surrounding breast tissue shows stiff (green, yellow, and red) content on shear-wave elastography image with average elasticity value of 115.4 kPa. (d): With strain elastography the small breast mass is blue corresponding to Tsukuba elasticity score of 4 (arrow). Both strain and shear-wave elastography helped the radiologist detect the lesion. Ultrasound-guided biopsy yielded the diagnosis of invasive ductal carcinoma grade 1. Both shear-wave and strain elastography yielded true-positive results.

the analysis of breast lesions. None of the breast radiologists from Québec or Canada routinely added sonoelastography to B-mode sonographic analysis of breast masses in their daily practice compared, to 17% of French radiologists.

Despite the encouraging results already reported in breast imaging literature for more than a decade from worldwide authors, these results support the assessment of Green, who noted that evidence-based practice often comes from artificially controlled research that does not fit the realities of practice [5,7,14,15]. Sonoelastography is an active area of research but “a rise in the amount of research results available does not automatically translate into improved patient care and treatment” [16].

There are multiple factors limiting the implementation of breast sonoelastography in daily clinical breast imaging practice. Some issues might be explained by the variety of available apparatuses and different nuances in the literature. In fact, the two main types of elastography techniques, strain and shear-wave, apply variable terminology and parameters on different commercial systems, which

can be confusing and render the training process laborious. For instance, color mapping for strain elastography based on Tsukuda score differs from color mapping used with the shear-wave technique, and in fact are exactly opposite (Figs. 1–5). Blue colored lesions in strain elastography are “stiff” whereas blue colored lesions with shear-wave elastography are “soft” [5,7,17]. Furthermore, both strain and shear-wave cut-off values vary according to different publications which constitutes a serious limitation in clinical practice [3]. Although most respondents in France and Québec use shear-wave elastography in clinical practice, a substantial number (13% of French respondents and 19% from Québec) do not know the type of elastography technique they use. This raises questions about their understanding of the technique and might explain the suboptimal usage of sonoelastography.

Another factor is related to difficulties encountered during the acquisition and interpretation times and the lack of reproducibility perceived by half of the radiologists in the survey (Fig. 3). One third of French and Canadian

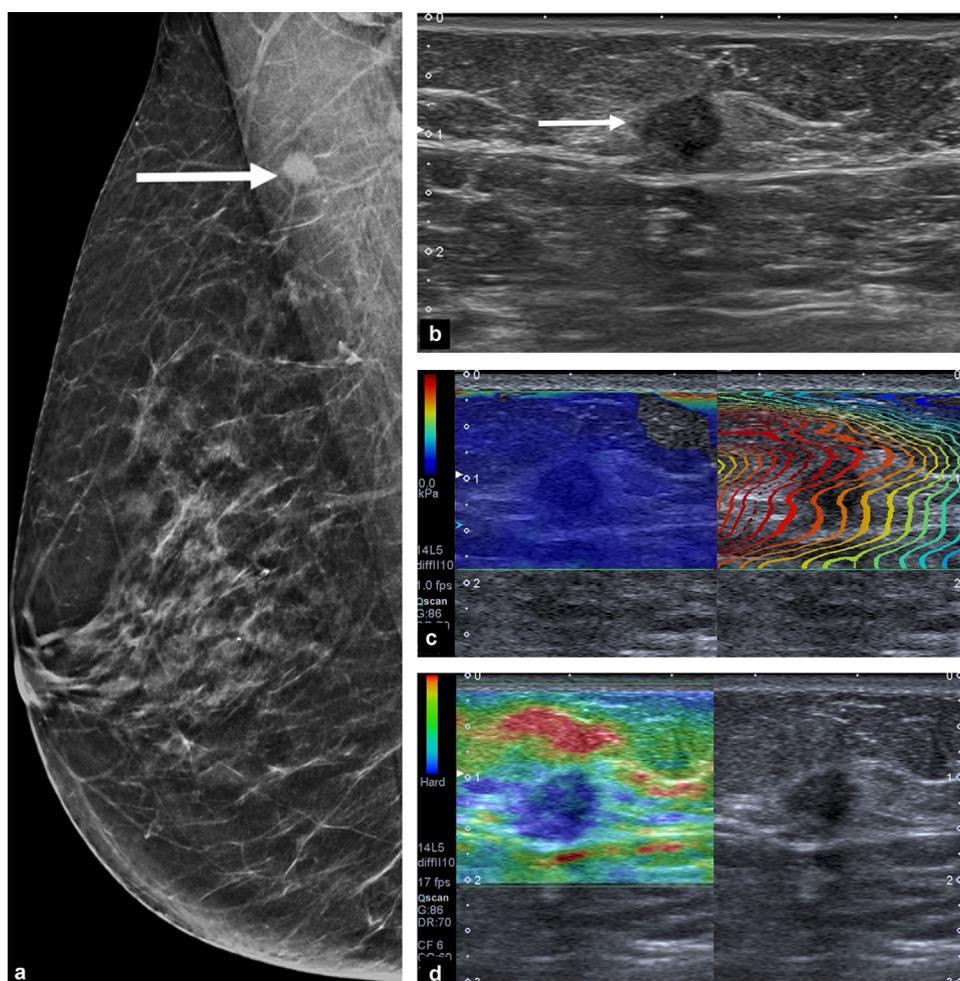


Figure 2. 59-year-old asymptomatic woman. (a): Screening mammogram (right medio-lateral oblique view) shows a 7 mm irregular dense mass in the axillary tail of the breast (arrow); (b): Ultrasound correlation shows an irregularly shaped hypoechoic mass (arrow) with microlobulated margins and surrounding echogenic halo, categorized BI-RADS IVc; (c): The mass appears homogeneously soft (blue) on shear-wave elastography image with an average elasticity value of 18.5 kPa; (d): With strain elastography, both the entire isoechoic lesion and slight surrounding region are blue, indicating a Tsukuba elasticity score of 5. Ultrasound-guided biopsy yielded the diagnosis of invasive ductal carcinoma Grade 2. Shear-wave elastography yielded a false negative result, whereas strain elastography showed a true-positive result.

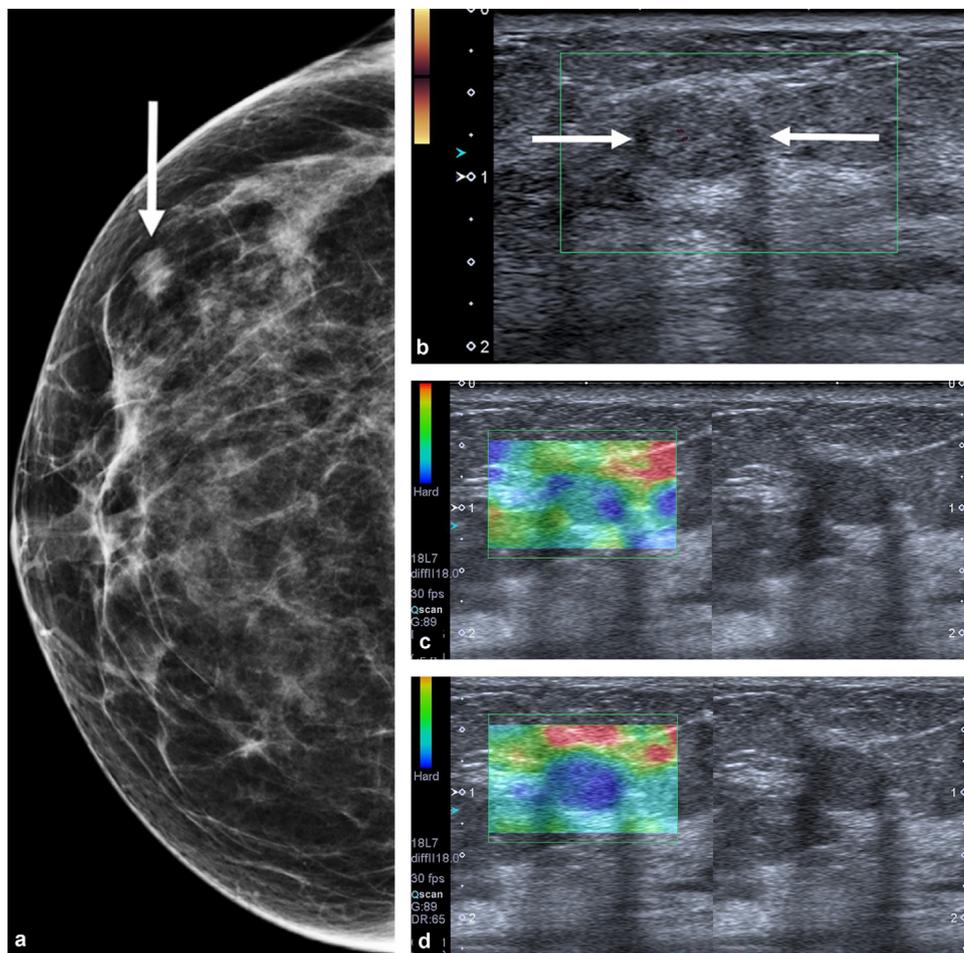


Figure 3. 52-year-old woman who underwent bilateral screening mammogram. (a): The right mammogram (cranio-caudal view) shows a new 7-mm oval shape mass (arrow); (b): Sonographic correlation shows an isoechoic, 7-mm oval mass, with well-circumscribed margins, categorized as BI-RADS IVa (arrows). (c,d), Two strain elastography images show; (c): a score 2 (most of mass is soft), and; (d): a score 3 (most of the mass is stiff) of Tsukuba. Ultrasound-guided biopsy yielded the diagnosis of fibroadenoma. Strain elastography yielded both true negative and false positive results.

respondents and two thirds from Québec admit mastering neither indications of breast sonoelastography nor interpretations of sonoelastographic images.

As with any other imaging technique, false positive and negative results as well as inter- and intraobserver variability may be encountered with breast sonoelastography (Figs. 2–6). In fact, because of their pathological features, some cancers such as Ductal carcinomas in situ are actually soft (Fig. 4) [18]. On the contrary, some benign lesions may be stiff and lead to false positive results, such as some fibroadenomas, radial scars, sclerosing adenosis or dense collagenous stroma (Fig. 5) [19]. Moreover, some radiological and anatomical features can favor false negative and false positive results. False negatives are more frequent when lesions are smaller than 10mm and deeply located within the breast [20,21].

Intra- and interobserver variability when acquiring images and assessing a lesion, is well reported especially when using strain elastography since different compression

techniques (pressure and speed of compression of the ultrasound probe) generate variable results [22,23]. A recent study suggested moderate interobserver reproducibility in breast strain elasticity image acquisition and poor interobserver agreement in image interpretation (Fig. 3) [24].

Shear-wave elastography also has limitations. This technique uses a focused ultrasonic beam that induces mechanical vibrations resulting in a transverse shear-wave that propagates faster in harder tissue compared to soft tissue and from which quantitative color-coded images and data can be obtained (Figs. 1,2,4–6) [25,26]. Unfortunately, there is a lack of standardization of sonoelastography techniques and investigators have used a variety of region of interest (ROI) sizes, reference tissues, and elasticity values during examinations [27]. For example, in determining the ROIs, some researchers have used the smaller ROI (diameter of 2 mm) in the stiffest portion of the lesion, whereas others have used the larger ROI to include the largest of the abnormal marginal tissue [27].

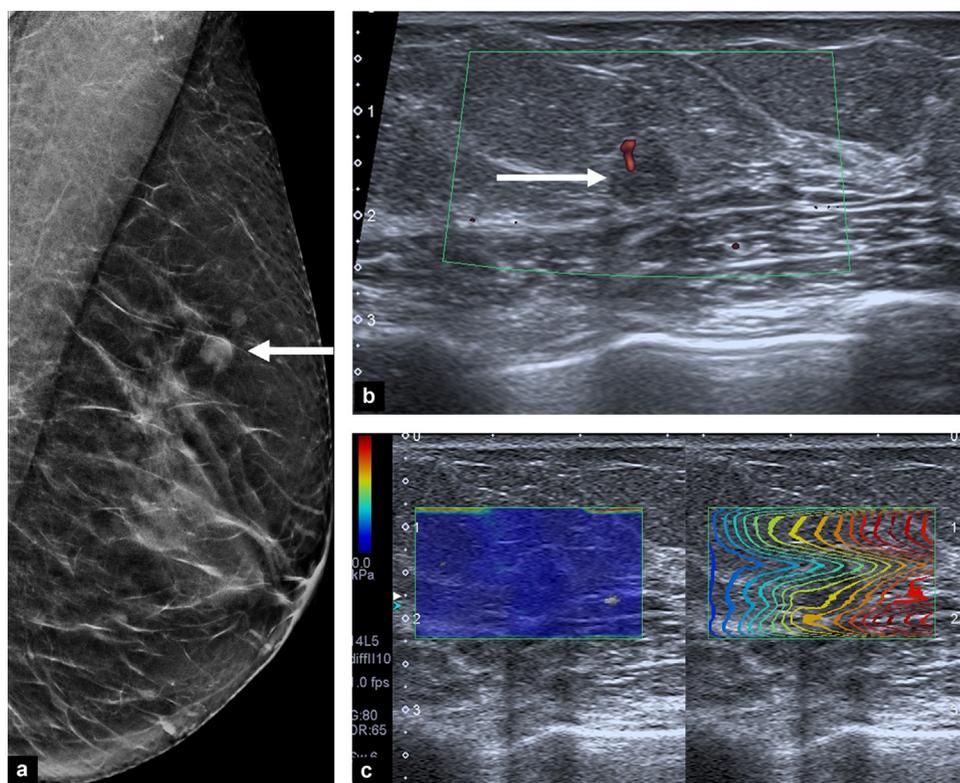


Figure 4. 55-year-old asymptomatic woman. (a): Screening mammogram (left medio-lateral oblique view) shows a new, well-circumscribed, 8-mm, round, dense mass (arrow) of the breast; (b): Ultrasound correlations shows an isoechoic, round mass with well-delineated margins (arrow), with a small feeding vessel identified at power color interrogation categorized BIRADS IVa; (c): The mass appears homogeneously soft (blue) on shear-wave elastography image. Ultrasound-guided biopsy yielded ductal carcinoma in situ. Shear-wave elastography yielded false negative result.

Solutions to optimize the use of the sonoelastography in daily practice

It is encouraging to note that, despite the lack of incorporation of sonoelastography in their routine practices, only 6–12% of respondents rated breast sonoelastography as useless. Additionally, almost 50% rated breast sonoelastography for analyzing breast lesions as a useful technique. What is really lacking for radiologists to embrace this new modality that could add useful information on sonographic analysis of breast lesions?

Understanding the indications

After the first publications showing that elastography alone had similar performance when coupled with B-mode ultrasound for breast lesions characterization, researchers realized that better results could be achieved when elastography was used as a complementary tool to morphological

features on ultrasound (shape, margins, echogenicity) in patients with indeterminate lesions (in practice, up-grade BI-RADS 3 lesions and downgrade BI-RADS 4a lesions) [7,28]. In particular, it was shown that elastography could improve specificity of B-mode ultrasound. As shown by our survey results, most radiologists, of all geographical regions, admit the usefulness of elastography mainly in lesion characterization and not in detection. Besides the differentiation of malignant and benign breast masses, elastography revealed itself useful for the evaluation of more subtle images, such as non-mass lesions on ultrasound, microcalcifications or small lesions on second-look ultrasound after breast MRI (Fig. 7) [29–31]. Nevertheless, these are advanced clinical situations, mostly encountered in specialized centers, in which the use of elastography is not straightforward and requires a good understanding and past experience of the technique. In any event, it is crucial to be aware that elastography is an adjunct to B-mode ultrasound and that stiffness should be considered as an additional parameter,

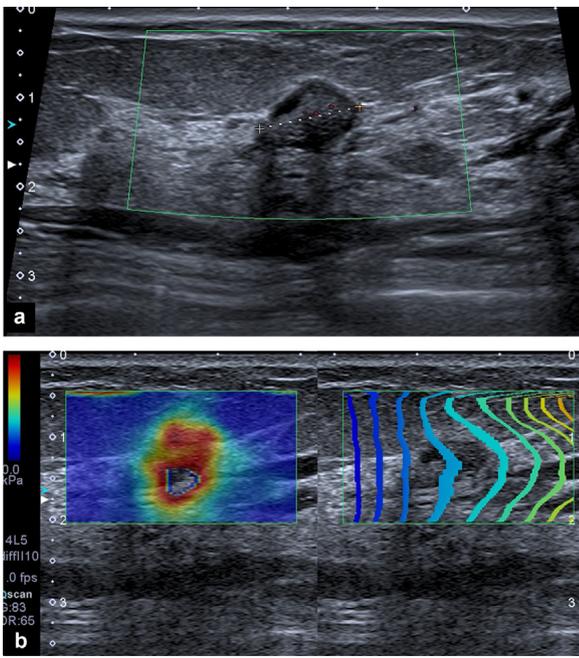


Figure 5. 60-year-old woman who underwent screening mammogram that shows heterogeneously dense breasts (not shown). (a): Screening bilateral breast ultrasound reveals a 10-mm, oval-shaped mass with well circumscribed margins and heterogeneous echotexture initially categorized BIRADS III; (b): Breast mass shows stiff (green, yellow, and red) content on shear-wave elastography image with an average elasticity value of 152.8 kPa, now categorized BIRADS IVa after elastography. Given the elastographic features, and despite a low suspicious appearance on B mode ultrasound, ultrasound-guided biopsy was performed and histopathological analysis showed benign changes (granuloma and foreign body related to former hematoma). Shear-wave elastography yielded a false positive result.

which should be interpreted with regard to morphological criteria. In case of important discrepancy between BI-RADS morphological features and elastography, it is important to keep in mind that B-mode ultrasound results should be privileged. In practice, a BI-RADS 5, 4b or 4c lesion should be biopsied even if it is soft on elastography.

Other potential applications of the technique include its potential use as a prognostic marker of breast cancers, or as a tool to assess early response to neo-adjuvant chemotherapy or even help evaluate axillary lymph node invasion of ipsilateral breast cancers. However, data in the literature are too limited for elastography to be used in clinical practice in these indications at this time [32,33].

Mastering the acquisition technique and interpretation

Radiologists should be aware of a learning curve, similar to other modalities, to be able to correctly acquire the images, analyze the findings and make conclusions while trying to minimize the factors that might hinder a good interpretation and lead to a false management. It is thus critical to learn how to optimize the examination and the subsequent interpretation. In fact, due to the high degree of variability, it is recommended to rely mainly on the color map, which is known to be more a qualitative assessment of stiffness than a quantitative one based on stiffness values [34]. The color map is a reflection of the stiffness value (Figs. 1–7).

Given that anatomical and radiological features may impact elastography results, it is important that they are considered when interpreting them. In particular, sonoelastography should be used with caution when the lesion is very superficial, i.e. located at less than 3 mm from the skin,

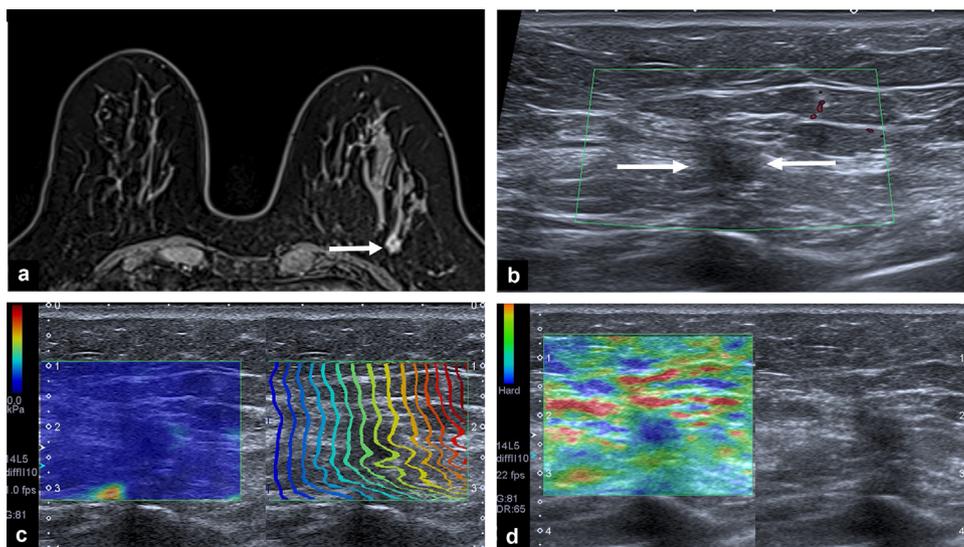


Figure 6. 62-year-old woman who underwent screening magnetic resonance (MR) imaging of the breast. (a): MR image in the axial plane shows an unexpected round 10-mm enhancing mass situated in the lateral aspect of the left breast. The mass displays a ring enhancement and was categorized BIRADS IVc (arrow); (b): Subsequent ultrasound identifies an irregular shaped hypoechoic mass with ill-defined margins, categorized BIRADS IVc (arrows); (c): The mass appears homogeneously soft (blue) on shear-wave elastography image with an average elasticity value of 20.1 kPa; (d): The mass appears homogeneously stiff (blue) on strain elastography image (Tsukuba score of 4). Histopathological analysis after ultrasound-guided biopsy revealed invasive ductal carcinoma grade II. Shear-wave elastography yielded a false negative result whereas strain elastography showed a true-positive result.

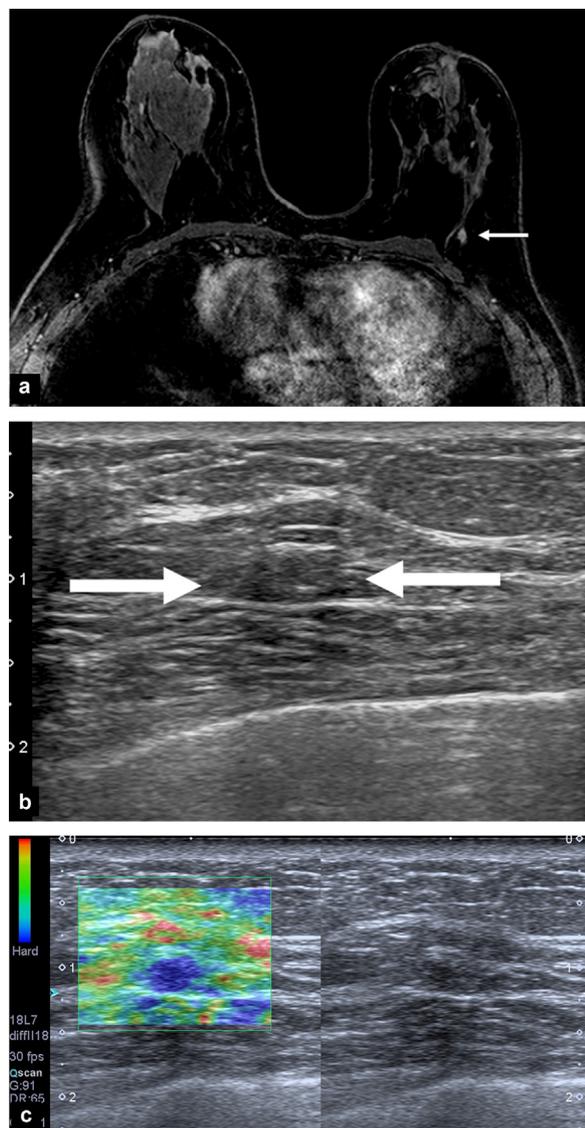


Figure 7. 58-year-old woman who underwent magnetic resonance (MR) imaging of the breast for preoperative staging (known right-sided invasive Grade 3 carcinoma). (a): MR image in the axial plane shows an unexpected, 7-mm, oval, enhancing mass in the left (contralateral) breast (arrow), classified as BIRADS IVb; (b): Subsequent MR-directed ultrasound identifies a questionable subtle, isoechoic oval mass, against a fatty background (arrows); (c): On strain elastography image, both the entire isoechoic lesion and slight surrounding region are blue, indicating a Tsukuba elasticity score of 5. Histopathological analysis after ultrasound-guided biopsy yielded the diagnosis of invasive ductal carcinoma Grade 2. Strain elastography yielded a true-positive result.

when deeply located, or when the lesion is larger than the field of view box [4,20].

Conclusion

As reflected by our survey, breast radiologists shy away from routinely using sonoelastography, which is perceived as an unreliable diagnostic tool and difficult to apply in daily practice. A good learning process and awareness of

the advantages and limitations of this technique may help motivate breast radiologists to use it to their advantage.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

Funding

This work did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

1) The scientific guarantor of this publication is Benoît Mesurolle.

2) Study concept and design: Benoît Mesurolle and Mona El Khoury.

3) Literature research: Simon Sun, Foucauld Chamming, Mona El Khoury, Michelle Zhang.

4) Clinical studies: N/A.

5) Data analysis: Foucauld Chamming, Mona El Khoury, Simon Sun, Michelle Zhang,

6) Moussa Keita kindly provided statistical advice for this manuscript.

7) Manuscript preparation: Foucauld Chamming, Mona El Khoury, Benoît Mesurolle, Michelle Zhang

8) Manuscript edition: Foucauld Chamming, Benoît Mesurolle, Simon Sun.

9) The authors state that this work has not received any funding.

10) The authors have approved the final article.

11) Institutional Review Board: N/A.

Disclosure of interest

The authors declare the following financial or personal relationships that could be viewed as influencing the work reported in this paper: Foucauld Chamming is a speaker for Supersonic Imaging.

References

- [1] Eisenscher A, Schweg-Toffler E, Pelletier G, Jacquemard P. Rhythmic echographic palpation. Echosismography: a new technique of differentiating benign and malignant tumors by ultrasonic study of tissue elasticity. *J Radiol* 1983;64:255–61.
- [2] Ophir J, Cespedes I, Ponnekanti H, Yazdi Y, Li X. Elastography: a quantitative method for imaging the elasticity of biological tissues. *Ultrason Imaging*, 13; 1991. p. 111–34.
- [3] Barr RG, Nakashima K, Amy D, Cosgrove D, Farrokhi A, Schafer F, et al. WFUMB guidelines and recommendations for clinical

- use of ultrasound elastography: Part 2: breast, *Ultrasound. Med Biol* 2015;41:1148–60.
- [4] Chang JM, Won JK, Lee KB, Park IA, Yi A, Moon WK. Comparison of shear-wave and strain ultrasound elastography in the differentiation of benign and malignant breast lesions, *AJR. Am J Roentgenol* 2013;W347–56.
 - [5] Itoh A, Ueno E, Tohno E, Kamma H, Takahashi H, Shiina T, et al. Breast disease: clinical application of US elastography for diagnosis. *Radiology* 2006;239:341–50.
 - [6] Burnside ES, Hall TJ, Sommer AM, Hesley GK, Sisney GA, Svensson WE, et al. Differentiating benign from malignant solid breast masses with US strain imaging. *Radiology* 2007;245:401–10.
 - [7] Berg WA, Cosgrove DO, Dore CJ, Schafer FK, Svensson WE, Hooley RJ, et al. Shear-wave elastography improves the specificity of breast US: the BE1 multinational study of 939 masses. *Radiology* 2012;262:435–49.
 - [8] Wojcinski S, Degenhardt F, Peisker U, Beussel S, Hahn M. Sonoelastography usage among German DEGUM-certified breast ultrasound specialists. *Ultraschall Med* 2014;35:59–66.
 - [9] Kopans DB. Breast imaging and the symptomatic patient: enough with the “diagnostic” mammography. *AJR Am J Roentgenol* 2003;181:1423.
 - [10] Clauser P, Mann R, Athanasiou A, Prosch H, Pinker K, Dietzel M, et al. A survey by the European Society of Breast Imaging on the utilisation of breast MRI in clinical practice. *Eur Radiol* 2018;28:1909–18.
 - [11] Thomassin-Naggara I, Jalaguier-Coudray A, Chopier J, Tardivon A, Trop I. Current opinion on clip placement after breast biopsy: a survey of practising radiologists in France and Quebec. *Clin Radiol* 2013;68:e378–83.
 - [12] Sickles E, D’Orsi CJ, Bassett LW, Appleton CM, Berg WA, Burnside ES, et al. ACR BI-RADS® Atlas Breast Imaging Reporting and Data System. America: American College of Radiology; 2013. p. 123–6.
 - [13] Regner DM, Hesley GK, Hangiandreou NJ, Morton MJ, Nordland MR, Meixner DD, et al. Breast lesions: evaluation with US strain imaging-clinical experience of multiple observers. *Radiology* 2006;238:425–37.
 - [14] Balleyguier C, Ciolovan L, Ammari S, Canale S, Sethom S, Al Rouhbane R, et al. Breast elastography: the technical process and its applications. *Diagn Interv Imaging* 2013;94:503–13.
 - [15] Green LW. Public health asks of systems science: To advance our evidence-based practice, can you help us get more practice-based evidence? *Am J Public Health* 2006;96:406–9.
 - [16] Kristensen N, Nymann C, Konradsen H. Implementing research results in clinical practice- the experiences of healthcare professionals. *BMC Health Serv Res* 2016;16:48.
 - [17] Yağcı B, Erdem Toslak I, Çekiç B, Öz M, Karakaş BR, Akdemir M, et al. Differentiation between idiopathic granulomatous mastitis and malignant breast lesions using strain ratio on ultrasonic elastography. *Diagn Interv Imaging* 2017;98:685–91.
 - [18] Park SY, Choi JS, Han BK, Ko EY, Ko ES. Shear wave elastography in the diagnosis of breast non-mass lesions: factors associated with false negative and false positive results. *Eur Radiol* 2017;27:3788–98.
 - [19] Elseedawy M, Whelehan P, Vinnicombe S, Thomson K, Evans A. Factors influencing the stiffness of fibroadenomas at shear wave elastography. *Clin Radiol* 2016;71:92–5.
 - [20] Vinnicombe SJ, Whelehan P, Thomson K, McLean D, Purdie CA, Jordan LB, et al. What are the characteristics of breast cancers misclassified as benign by quantitative ultrasound shear wave elastography? *Eur Radiol* 2014;24:921–6.
 - [21] Yoon JH, Jung HK, Lee JT, Ko KH. Shear-wave elastography in the diagnosis of solid breast masses: what leads to false-negative or false-positive results? *Eur Radiol* 2013;23:2432–40.
 - [22] Schwab F, Redling K, Siebert M, Schotzau A, Schoenenberger CA, Zanetti-Dallenbach R. Inter- and intra-observer agreement in ultrasound BI-RADS classification and real-time elastography Tsukuba score assessment of breast lesions. *Ultrasound Med Biol* 2016;42:2622–9.
 - [23] Lacout A, Figl A, Thariat J, Marcy PY. Intra- and interobserver variability of US elastography: how does it affect quality? *Radiology* 2011;260:610.
 - [24] Dong Y, Zhou C, Zhou J, Yang Z, Zhang J, Zhan W. Breast strain elastography: Observer variability in data acquisition and interpretation. *Eur J Radiol* 2018;101:157–61.
 - [25] Cong R, Li J, Wang X. Comparing performance of combinations of shear wave elastography and B-mode ultrasound in diagnosing breast masses: is it influenced by mass size? *Ultrasound Med Biol* 2017;43:2133–43.
 - [26] Hari S, Paul SB, Vidyasagar R, Dhamija E, Adarsh AD, Thulkar S, et al. Breast mass characterization using shear wave elastography and ultrasound. *Diagn Interv Imaging* 2018;99:699–707.
 - [27] Moon JH, Hwang JY, Park JS, Koh SH, Park SY. Impact of region of interest (ROI) size on the diagnostic performance of shear wave elastography in differentiating solid breast lesions. *Acta Radiol* 2018;59:657–63.
 - [28] Evans A, Whelehan P, Thomson K, Brauer K, Jordan L, Purdie C, et al. Differentiating benign from malignant solid breast masses: value of shear wave elastography according to lesion stiffness combined with greyscale ultrasound according to BI-RADS classification. *Br J Cancer* 2012;107:224–9.
 - [29] Ko KH, Jung HK, Kim SJ, Kim H, Yoon JH. Potential role of shear-wave ultrasound elastography for the differential diagnosis of breast non-mass lesions: preliminary report. *Eur Radiol* 2014;24:305–11.
 - [30] Cho N, Moon WK, Park JS. Real-time US elastography in the differentiation of suspicious microcalcifications on mammography. *Eur Radiol* 2009;19:1621–8.
 - [31] Plecha DM, Pham RM, Klein N, Coffey A, Sattar A, Marshall H. Addition of shear-wave elastography during second-look MR imaging-directed breast US: effect on lesion detection and biopsy targeting. *Radiology* 2014;272:657–64.
 - [32] Seo M, Sohn YM. Differentiation of benign and metastatic axillary lymph nodes in breast cancer: additive value of shear wave elastography to B-mode ultrasound. *Clin Imaging* 2018;50:258–63.
 - [33] Evans A, Armstrong S, Whelehan P, Thomson K, Rauchhaus P, Purdie C, et al. Can shear-wave elastography predict response to neoadjuvant chemotherapy in women with invasive breast cancer? *Br J Cancer* 2013;109:2798–802.
 - [34] Hong S, Woo OH, Shin HS, Hwang SY, Cho KR, Seo BK. Reproducibility and diagnostic performance of shear wave elastography in evaluating breast solid mass. *Clin Imaging* 2017;44:42–5.