Sonoelastography in Addition to Doppler Ductal Echography: Full Breast Ultrasonography

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4.1 Definition of the Sonoelastography: Systems of Acquisition

Elastography refers to the measurement of the elastic properties of the tissues, based on the well-established principle that malignant tissue is harder than benign tissue. The standard medical practice of soft tissue palpation is based on qualitative, low-resolution assessment of the static elastic modulus of tissues. Pathological changes are generally correlated with changes in tissues' elastic modulus, and breast palpation is the first diagnostic method, early used by Hippocrates, with an accuracy evaluated to 60–65 %. The different response to the compression with the transducer of the benign or malignant lesions was early published in 1977 on statically images by Kobayashi, which presented the deformation of the tissues with increasing posterior enhancement effect and of the lateral shadows for benign masses, while the malignant ones presented less compressibility but increasing shadowing [1, 2].

We agree in general that a lesion may not possess echogenic properties which could make it ultrasonically detectable, such as prostatic tumor or hepatic cirrhosis or breast tumor in classical US [3, 4], but we deny this affirmation for Doppler DE, because there are no cases of breast tumor undetectable on DE, confirming the opinion of the promoters of this method [5]. When adding sonoelastography, we are able both to better visualize the differences between the suspect abnormality and the surrounding breast tissues and to characterize its risk of malignancy.

To assess the elasticity, it is necessary to apply an external mechanical stimulus to the tissues and to observe the response in terms of local internal deformations. In principle, any high-resolution imaging modality may be used for such observations. The use of ultrasound for this purpose, however, has several important advantages such as real-time imaging capabilities, very high resolution in motion estimation (~1 μm), simplicity, noninvasiveness, and relative low cost, as compared with MRI elastography.

In clinical practice, sonoelastography was used by some authors as a single method of diagnosis, with doubtful accuracy as compared with US alone [6], but we recommend combining sonoelastography with the ductal, even with the conventional, ultrasound, using them as complementary diagnostic tools, similar to Doppler used in addition to US B-mode examination. *Elastography is only another descriptor of a tissue/tumor* such as margins, echo texture, and posterior effects, and it is illogical to compare its performance with US alone, while nobody compared Doppler exam with 2D US alone.

Conventional elastography, i.e., the process of imaging the axial strain in tissues that occurs in response to a known external displacement, ignores many properties of the tissue's response to an applied stress. Elastography uses raw ultrasound obtained before and after a slight compression of tissues, typically achieved with a transducer. Compression may also be performed using vibrations in a technique known as real-time sonoelastography (RTSE). Elastography measures and displays strain represented by the change in the dimension of tissue elements at various locations in the region of interest. It is known that substantial strain contrast is due to the stress distribution that is specific to the boundary conditions of the experiment, rendering strain images non-quantitative. Moreover, it seems that such elastogram is influenced by, and sometimes contains information about tissue properties (viscosity, porosity, anisotropy, nonlinearity of the stress-strain relationship). In clinical applications, quantitative imaging may improve ability to distinguish benign from malignant tumors and may open up new applications such as monitoring the effects of and response to treatment; it is also expected to improve lesion visibility and imaging understanding, by reducing image artifacts, such as the retroareolar shadowing or false microcalcifications in nodular fibro-micro-cystic dysplasia.

Different approaches on the elasticity imaging have been investigated, and at present some are at the stage of developing the practical system. In clinical measurement, a

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high-speed processing is required for real-time diagnosis, and freehand manipulation of ultrasonic probe like the usual ultrasonic diagnosis is desirable for simple operation. The American achievements concerning 15 years of research about tissues' elasticity were presented justly to the *2006 ECR* by Ophir et al., from Texas, who have constructed a device based on a Philips imaging system designated to produce elastography of the breast in vivo [4], while at the *2005 RSNA* meeting, tomosynthesis was the most important breast imaging development. Elastography was earlier developed in Japan by Shiina and Ueno, which at the beginning of the nineteenth century conceived a real-time tissue elasticity imaging system (consisting of an ultrasonic 7.5 MHz probe, an ultrasonic scanner, and a personal computer Intel Pentium IV), with freehand tissue compression based on the extended combined autocorrelation method [7], and the results were presented in 2003 [8]. Furthermore, their method was implemented and developed on the Hitachi devices.

Nowadays, there are two available types of equipments for sonoelastography:

a. The equipment from Hitachi Medical Corporation, completed in 2003 and commercialized and marketed since 2004, which uses mechanical external or better freehand compression of tissues, *HI-RTSE (Hitachi Real-time Tissue Elastography)* with two rendering methods: a qualitative and a quantitative sonoelastography. The *qualitative method* uses a color scale from red for the soft, normal structures to blue, for stiff, malignant lesions. This scale comports a classification named *Ueno* (promoter) or *Tsukuba* (the University), which will be presented on what follows and used as the best scoring system. Hitachi equipments include a *quantitative* sonoelastography too, which is more accurate and calculates the *strain ratio* or *fat-to-lesion ratio (FLR)*, with a cutoff established at 4.7 (5.0 as maximum), that means lower FLR is found in most probable benign conditions and higher is found in the malignant lesions. It is recommended by the manufacturer to select the ROI for the pathological area ("B" area) and for the normal fatty tissue area ("A" area) for the calculation of the strain ratio (B/A) on the 2D grayscale display, because some benign lesions may be not visible on the color display; other sonographers recommend to select the ROI on the color display, because the pathological area is better delineated especially in the malignant lesions [9]. Practically, both methods are used together and offer similar results, because the HI-RTE is easy to perform, fast, accurate, and reproducible.
b. The equipment from Siemens, experimented mainly by British and Italian radiologists and promoted by American researchers from Texas, *eSie Touch™ elasticity imaging*, which uses a specialized software for imaging the relative tissue compression; practically the tissue elasticity is investigated using an "internal palpation" produced by the ultrasonic wave front compression and ultrafast measuring of their displacements. Rendering the elasticity, elastograms were presented in both *a 2D log grayscale* less used because of less sensibility and less resolution and in a *color scale*, initially with inversed colors as compared with HI-RTE, from violet for normal/benign structures to red for stiff/malignant ones. Nowadays, there are optional color scales with less popularity.

Initial studies of English researchers demonstrate a significant reduction of benign unnecessary biopsies; moreover, because elastography overestimates the size of many malignant tumors because the peritumoral stromal reaction is best delimitated, it was considered useful for guiding surgery, with re-excision rates being reduced. Using comparative freehand strain imaging of the Siemens equipment, it is possible to halve the benign biopsy rate when using a strain/B-mode ratio of 75 % as the cutoff point [10]. Unfortunately, the system has not been widely promoted in the USA, and it is being used only at a handful of research facilities, because in the USA there is a greater tendency to biopsy breast lesions and the manufacturer development is mainly oriented to breast MRI or the improvement of full-filed digital mammography, CAD, PET-CT, and tomosynthesis, which are more operator independent but are more expansive, less available, and do not have completely less side effects (even MRI could have some side effects of the paramagnetic contrast agents or directly on the nervous system).

Therefore, there are new developments of the techniques of elastography, such as *ShearWaveTM Elastography* presented at the ECR 2009 by The Theragnostic CompanyTM on a platform named the AixplorerTM Ultrasound System, which measure the quantitative elasticity in kilopascals, offering user-skill-independent and reproducible results with a remarkable image quality.

While manufacturers have patent disputes, the two main sonoelastographic systems coexist; therefore, the color scale from Hitachi with the scoring system of the tissues' elasticity, superposed on the BI-RADS classification, named upon the University of Tsukuba or upon the main promoter Professor Ei Ueno, is already more familiar, and many researches confirmed its viability, so this method will be mainly presented and illustrated in this volume. Many manufacturers implemented in the last years this scale and the strain ratio upon Hitachi (such as Aloka, Toshiba, General Electric), resulting to an almost standardized technique of examination.

4.2 Accuracy of the SE

There are not yet many published studies with sonoelastography applied to DE, except for a few works of their promoters and other disciples [5, 9, 11, 12], so the most published

results represent the applications on classical breast US. Even with the classical US, which is itself less performing, the results of sonoelastography revealed a revolutionary technique, relatively cheap, noninvasive, available, without side effects, and with reduced emotional burden, thus being repeatable and suitable for screening and the best recommendable for the differential diagnosis of benign from the malignant masses in soft tissues, such as the breast, thyroid, musculoskeletal US, or in deep organs, such as the prostate, liver, uterine cervix, or kidney.

For lesions of all sizes, classical breast US elastography using Hitachi technique achieved sensitivity of 80 %, specificity of 93 %, positive predictive value of 85.3 %, and negative predictive value of 90.3 %, in a French report in 2006 consisting of elastography applied in classical US [13]. Sensitivity was the best for lesions less than 5 mm (90 %), while specificity was the best for lesions over 10 mm (95 %). Researchers also reported false positives with elastography (such as fibrous mastopathy and sclerosis adenosis) and false-negative findings (such as DCIS). Other results are in favor of sonoelastography, avoiding unnecessary biopsies, with accuracy between 95 and 99 % [14]. There are yet doubts about the ability of sonoelastography to prove definitely if a lesion is benign or malignant, and there are opinions that even if elastography indicates a lesion as benign, if another feature looks suspicious, the biopsy might still go ahead. The doubts are partially justified, in our opinion, on one hand because of the yet no standardized technique of examination in elastography, with two systems, two scales, less trained operators, and less known method by the clinicians, and on the other hand because of the irrational, classical, non-anatomical approach of the breast in classical US, resulting to false limits of sonoelastography.

In fact, a good anatomical US technique of examination of the breast, combined with Doppler characterization of the lesions and sonoelastography, results in an accurate prediction of the malignancy of the breast lesions. None technique was proved to be sufficient to assess the malignancy risk, but the Doppler features combined with sonoelastography are able to increase the performance up to 100 %; as consequence, this duality of Doppler-sonoelastography applied to DE represents the trinity named the full breast ductal Doppler ultrasonography or briefly full breast ultrasonography (FBU). The major fault of the previous reports is the lack of correlation between Doppler and sonoelastography. For instance, the false-positive fibrous mastopathy, fibrous-micro-cystic dysplasia, and sclerosis adenosis may mimic a breast cancer on classical US with sonoelastography, but in DE they have different aspects; moreover, usually these dysplasias have less/absent salient vasculature, while cancers have new formation vasculature visible in Doppler as well as in contrast MRI (where vasculature determines the enhancement curves characterizing the malignancy risk). Contrarily, the false-negative DCIS/LCIS on classical US with sonoelastography appears in FBU as a lesion less than 5 mm in diameter with ductal localization/connection and with detectable increased focal vasculature, which is suspect for malignancy. In all cases, we recommend the use of the quantitative FLR for sonoelastography, because the results are more specific for cancer than with the qualitative elastography alone.

4.3 Technique of Sonoelastography: Integration in FBU

There are few steps recommended in the FBU examination:

I. *Detection*: A radial scanning of the entire breast (DE) with the long probe, using a water-bag adaptor and noticing all the abnormalities (L3:00, R12:00); usually 7–10 MHz probes of 7–9 cm length are the best available, resulting a compromise between the length radial scan and the frequency related to the image resolution.

   This technique is standardized by Teboul et al. and is recommended in screening, with better sensibility than that of the mammography.

II. *Characterization of US BI-RADS applied to DE:* A reexamination of the solid or suspect lesions concerning all criteria of the Stavros in 2D and 3D/4D US, using DE (the radial technique), is performed with a very high-frequency probe, usually of 4–5 cm in length and up to 16 MHz, which offers a better resolution; the high resolution in DE is the key for better characterization of the ductal-lobular "tree" and of the abnormal ultrasound findings.

   This examination includes the characterization of the vasculature on Doppler imaging, using especially the qualitative analysis of the vessels, in the radial, antiradial, and 3D acquisitions.

   This step is standardized for DE and the US BI-RADS assessment; it maximizes the sensibility and offers a high specificity of breast US for benign and malignant lesions. Some manufacturers produced linear transducers of intermediate length of approximately 6–7 cm, multifrequency, with good resolution for all depths and with possibility of virtual radial scanning, which can be used instead of the two types successively as described above; that results in good evaluation of the mammary lobar radius and good assessment of the vasculature and of the tissue stiffness.

III. *Characterization of the stiffness*: The third step is represented by sonoelastography applied to each lesion found before and to the retroareolar structures. Every lesion must be initially characterized in B-mode and color Doppler, because on the real-time dual image display sonoelastography (with elastogram and B-mode image), the internal echoes and the marginal regions of

the lesion cannot be evaluated properly, because the pressure given with the probe is too weak for a good US image. The qualitative sonoelastogram is standardized basing on the Ueno/Tsukuba score, and the quantitative sonoelastography is referring to the fatty tissue strain (FLR), being less operator dependant and increasing the specificity of the FBU over 90 %. The examination will be accomplished with the assessment of the satellite lymph nodes, with the high-frequency transducer, including the Doppler and sonoelastography applications.

According to most authors and our experience, a FLR less than 4.70 (5.00) at repeated measurements is high, predicting for a benign breast structure, and is correlated with the scores 1, 2, and 3 Ueno and BGR; when FLR is around 5.00 (4.50–6.00), a borderline structure may be affirmed; malignancies with score 4 or 5 Ueno present usually a high FLR value, usually over 10.00, and its value is as high as the lesion that may contain (unapparent in US!) malignant microcalcifications or strong desmoplastic reaction. It is recommended to assess FLR better as interval or the superior limits for benign findings and the most inferior values for the malignant-type lesions, and to avoid affirming a precise value for FLR.

This sequence is the most performed examination, and its efficacy was proved by Amy and other promoters [9, 15, 16]; in fact, this sequence is logical, and any other sequence could be incomplete and will increase the risk of misdiagnosis or will impose supplementary tests (i.e., biopsies or breast MRI). The first step will explore the whole breast; the second and the third will characterize each lesion with complementary findings for the final diagnosis. The whole examination of both breasts, for trained operators, takes about 30 min, and the patient is informed immediately and without any harmful procedure about the diagnosis and about the recommendations, without any waiting stress and supplementary expenses.

For the best accuracy of sonoelastography, it is recommended to use the highest-frequency available transducer, without water bag. We can perform this exam in any plan of the breast volume, but it is logical to initiate it in the same radial plan that realize the detection and the establishment of the rapports of the lesion. A small compression pad could be attached to the probe/transducer, so that stable tissue compression is attained and the stress field is more uniformly transmitted. The compression with a stepping motor could be better because the compression direction is the same as the axial direction of the ultrasonic beam, the best for strain estimation. However, the freehand technique is preferred as in the usual ultrasonic diagnosis, and a good training and the use of the combined autocorrelation method of Shiina and Ueno can suppress the lateral slip. When applying freehand technique, a light pressure with a soft touch is preferable, because a strong pressure produces strain even in hard tissue, providing erroneous information.

There are two possibilities of achieving freehand elastograms [7]:

- Making a small compression on the region of interest, with uniform release, this technique is more difficult to train to the operators and somewhat subjective.
- Making fine, 1 mm movement in normal breast, up to 2 mm for deeper lesions or for large breasts; the movement consists in quick series/cycles of 2–3 s of compressions, obtaining a real-time elastogram. This method is easy to perform and to train, and the results are reproducible.

Because the level of the strain changes while compressing or relaxing the tissues, Shiina and Ueno calculated the mean of strain distribution within a ROI, with a maximum range set of 2.5 times the mean value and the minimum set of 0, so the stable strain image is no more depending on the level of compression.

After selecting the elastography mode, we must set up elastography ROI according to the size of the lesion and thickness of the mammary grand. The elastogram shows the distribution of the relative strain, so adjacent normal breast tissue must be included in the ROI:

1. In the depth direction: from subcutaneous tissue to pectoralis major muscle
2. In the width direction: full range of the screen

The display will be adjusted so that the lesion occupies a quarter of the screen width or less. If the lesion is larger than a quarter, we must change to a smaller cross section. When selecting a wrong ROI, the same lesion might appear different depending on ROI size, for instance, for a too small wrong ROI, the lesion may appear as benign (score 2 Ueno), but for a good large ROI, the lesion may be typically malignant (score 4 or 5 Ueno). If the tumor size is large, the recommendation of the manufacturer is to move tumor position from the center to the edge of the ROI, and then we will be able to compare it clearly with the normal surrounding tissues.

Training the operators is essential, because a wrong technique may result misdiagnosis. The probe is placed on the breast so it is not deformed and the movement of 1–2 mm up and down is made from this position, with an optimal frequency of 2 Hz (2cycles/second). If the initial compression is too strong, when performing sonoelastography, the normal tissues are in tension, their elasticity is reduced in that position, and the eventually stiff tumor has similar score, so the result is false negative. The probe must be fixed to not laterally sliding, and it is useful to anchor the operator's hand by resting the fifth fingers on the breast skin. The acquisition is accomplished when reproducible elastogram is obtained.

4.4 Rendering Sonoelastogram

The ultrasonic echo signals from the inside of a tissue, before and after deformation during the compression and the relaxation made with the transducer, are measured simultaneously, and a displacement distribution of each point is estimated. Then, the spatial displacement distribution is visualized as an elasticity image. Using a base algorithm of the combined autocorrelation method, the system can estimate the strain distribution accurately and at a high speed, supporting a large dynamic range of strain, with a lateral slip to about 4 mm. Tissue hardness is displayed in color tone, with increasing hardness presented in descending order of red, yellow, green, and blue on the Hitachi model, or optional in the inversed order on other platforms.

Because the area and the boundary of the tumor in a strain image and B-mode image are not necessarily the same, for recognition, the corresponding area in the two images was imagined in a way to display both images simultaneously: a strain image is superimposed on the B-mode image with a translucent color scale, where, for example, red indicates that the tissue is soft and blue indicates that the tissue is hard/stiff. In the dual elastographic mode, we have on the left side of the screen the B-mode display and on the right side the strain image for the ROI superimposed on the B-mode image. The system allows us to verify the range of stream and repeat the acquisition if it is not optimally situated in the manufacturer recommendations. That results an operator-independent technique, without significant differences between different compressions ranges. For each ultrasound machine with a particular patent of sonoelastography, there is a specific modality to display the level of the pressure applied during the acquisition; the manufacturers offer the possibility to self-control the compression intensity and to immediately correct when it is out of recommended limits. Obviously, only the correct acquisitions must be interpreted and reported.

4.5 Interpretation of the Elastogram

The color-coded elastograms are similar, but not entirely superposing images to B-mode achievements, because they measure not only the elasticity of the researched mass but the effect of the mass to the surrounding tissues. For example, for the fibroadenoma, the area on strain display is either absent/indistinct and if a small lesion, either smaller than in B-mode or equal. Inversely, for the malignant masses, the strain image is either equal (if there aren't surrounding infiltration produced by the desmoplastic reaction) or larger, the central tumoral dark blue area being surrounded by a boundary light blue or halo, corresponding to the peritumoral malignant infiltration or to the peritumoral desmoplastic reaction.

When analyzing the real-time dual image display during the exam, it is recommended to look at the elastogram image, because when looking on the grayscale image, the resolution is not very good and there is tendency to push too hard with the probe, which can produce false-negative images. Another key is to review the record of the dynamic acquisitions: if the scores vary, the initial pressure may be too high or compression movement too large, and the sonoelastography must be repeated. If the acquired breast images have the same score during compression in the dynamic image, the operator's performance is validated, and the elastogram will have high diagnostic value.

The classification system developed by Ei Ueno is already largely accepted, because it is practically easy to recognize and especially because it is pathologically correlated, almost superimposable on the US BI-RADS classification. The Italian score is a variant less utilized, where the score 1 is represented by the cystic aspect and some small differences are presented for the other scores, but without significant diagnostic improvements.

4.5.1 The Elasticity Score Named Upon Ueno/Tsukuba University: Benign

Score 1: Entire area is evenly shaded green, as is surrounding tissue (Figs. 4.1, 4.2, and 4.3). DE presents the normal ducts and lobules in green yellow and interprets the score 1 Ueno, while the small ectasias have the ductal walls in green and the content of the lumen colored in red, with the same score 1.

Score 2: Lesion area shows a mosaic pattern of green, blue, and red (Figs. 4.4, 4.5, and 4.6). The DE illustrates for the different ROI of a mammary lobe including parenchyma and glandular stroma, a score 2 Ueno, which is considered as normal. The normal satellite lymph node sonoelastogram may appear as score 1 or 2 Ueno.

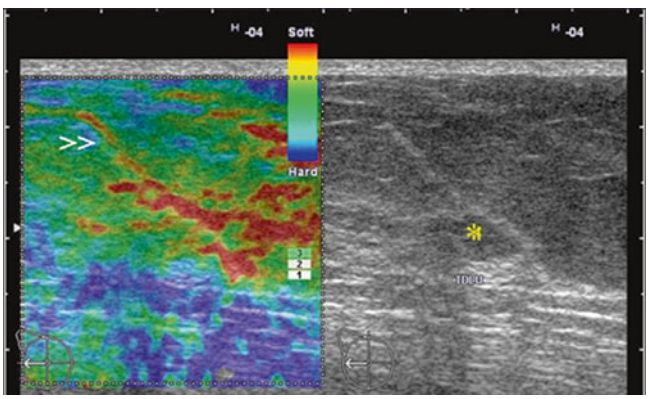

Fig. 4.1 Sonoelastography in fatty breast with ductal atrophy, difficult to differentiate from the fatty tissue, with the score 1 Ueno; there are some salient remnant glandular structures in a TDLU (*) and along the Cooper ligament, which appears "elongated" (>>). The pectoral muscles are normally stiff (US BI-RADS 1 category)

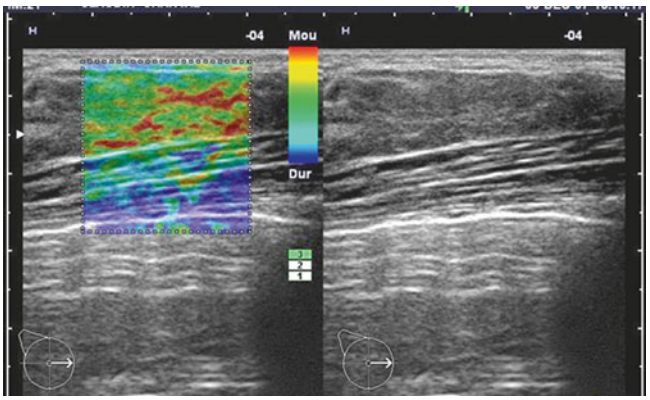

Fig. 4.2 Sonoelastography in dense glandular breast dystrophy in a thin woman, with almost absence of subcutaneous and retromammary fatty tissue, reduced glandular stroma with contiguous "back-to-back" ducts and lobules on DE, presenting normal architecture on the elastogram—score 1 Ueno for normal parenchyma (US BI-RADS 1 category)

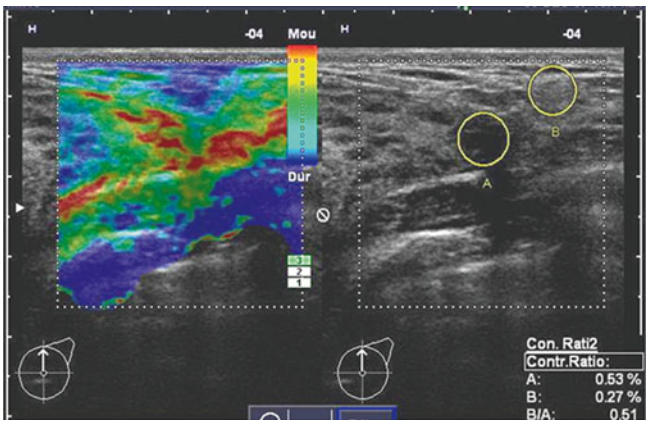

Fig. 4.3 Sonoelastography is the best choice in the pseudomalignant US findings: DE shows a suspect lesion, based on the classical US features; in this case an US lesion type BI-RADS 4–5 category presents an elastogram score 1–2 Ueno and a very low FLR, high suggesting for benign lesion, avoiding unnecessary biopsy (US BI-RADS 2 category)

Score 3: Central part of the area is blue (stiff), and peripheral part is green (soft), so the lesions appear smaller on the elastogram than in the grayscale display. Score 3 is a state in which malignancy cannot be ruled out, but it is usually applied for some fibroadenomas (Fig. 4.7).

4.5.2 Malignant

Score 4: The entire area is blue (stiff), with the same size as the area on the grayscale; the malignant lesion is well delineated, usually noninvasive small cancer or particular types such as mucinous or medullary cancer (Fig. 4.8). The intracystic or intraductal carcinoma is typical for the score 4 Ueno, but very aggressive, undifferentiated invasive cancers with rapid growth that do not allow the desmoplastic reaction to develop may equally present the score 4 Ueno.

Score 5: The entire area and its surrounding area are blue (stiff), so the lesion appears larger on the elastogram. This corresponds to the typical scirrhous carcinoma with peripheral desmoplastic reaction that shows a light-blue halo, corresponding in B-mode to the hyperechoic signal at the border determined by the malignant halo and to the attenuated echo on the posterior side (shadowing) (Fig. 4.9). Score 5 is not specific for malignancy, but for any hardness of the tissues, such as scars, fibro-micro-cystic disease especially the nodular form, chronic inflammation, or fibrosis related to the implant pathology.

However, these scores can be considered to correspond to the assessment category of BI-RADS [17], but we must be precise for the final diagnosis of the sonoelastography and must rely to the Doppler characterization.

In addition, for the cysts larger than 5 mm, a special score was described, a composed image with two internal level-level structures, represented by *blue/green/red (BGR) complex* that is characteristic for the liquid, and the same aspect appears in abscess, hematoma, seroma, and implants, as well as in the cross section of the large vessels (Fig. 4.10). In cases of nodular fibro-micro-cystic dysplasia, the fluid content of the immeasurable cysts on US determines the BGR-summation score, with the unique elastogram BGR being equivalent to those of a cyst of equal size as the sum of the cluster of microcysts (Fig. 4.11). In other cases, there is a complex of BGR-summation score (Fig. 4.12), either in a large dysplasia or in a multiloculated hematoma, area of edema, recent large scar, infected cysts or galactoceles, and other benign conditions. It is remarkable that mucinous carcinoma appears always as malignant, without BGR score. By consequence, the proper use of sonoelastography as a complementary method allows a better interpretation of the Doppler DE or of the Doppler classical US.

Observation The Ueno score classification system was conceived in classical US, despite the group of researchers that the coordinates are familiar with in the ductal US approach. That means some terms such as *surrounding tissue* adopted by the practitioners of the classical US which represent in fact the surrounding stromal components, while the breast parenchyma may appear green or red; especially ductal-lobular benign hyperplasia is green yellow, while small ductal ectasia appears in red in the central luminal area, due to the presence of the liquid, bordered by the ductal walls in green yellow. Nevertheless, the largest duct ectasias will illustrate a similar BGR scoring as the cysts with a ribbon shape.

The value of sonoelastography is revealed in such conditions by confirming the malignancy in hyperechoic breast cancer (when it is surrounded by fatty tissue, which is

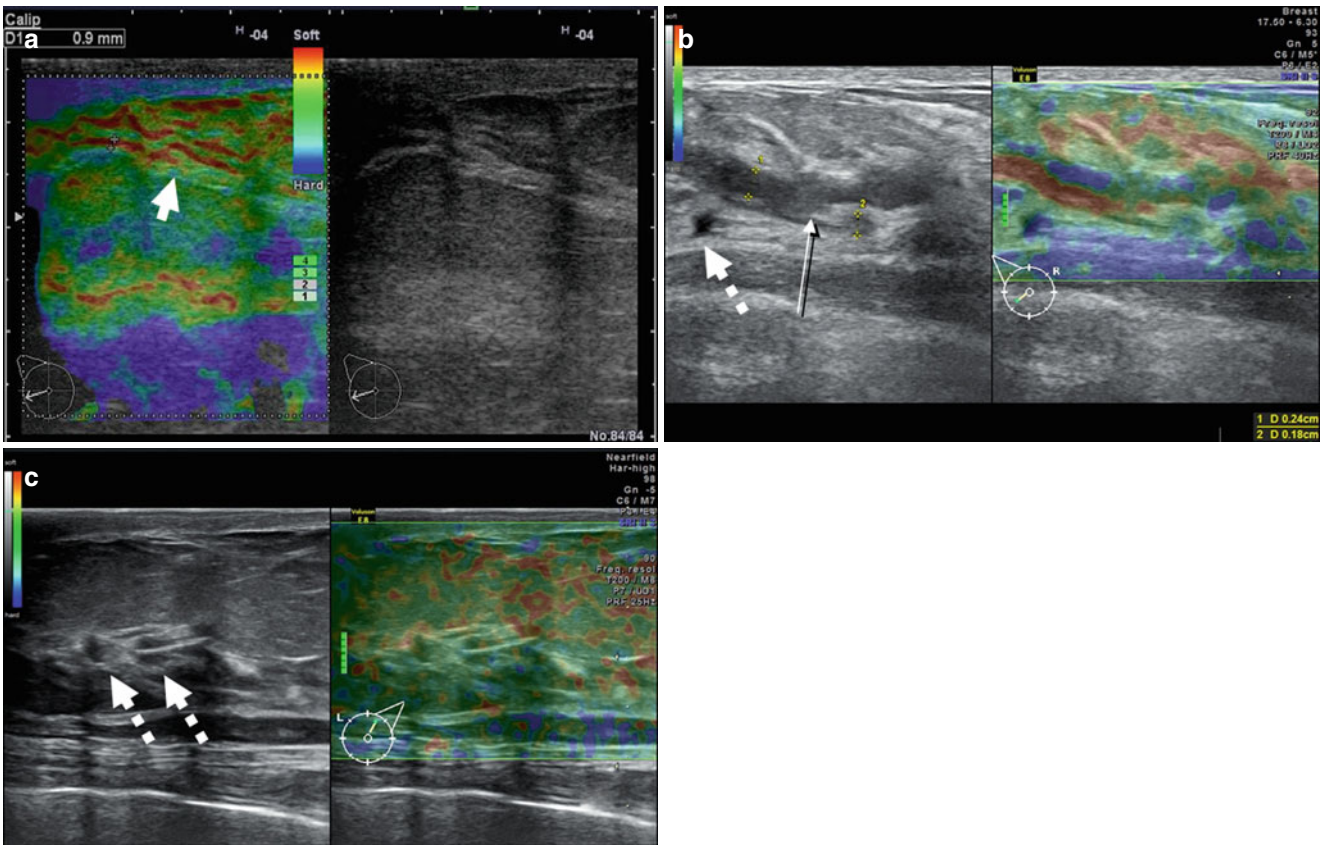

Fig. 4.4 Sonoelastography of normal heterogeneous breast (**a**), with thin, less than 1 mm in diameter ducts, scored 1 Ueno; duct ectasia of 2.4 mm in diameter (**b**) with BGR score (*long arrow*). Lobules may be visible usually in young, adult dense breast or in adenosis (**c**), with global sonoelastography of the mammary lobe score 2 Ueno (*square dot arrows*)

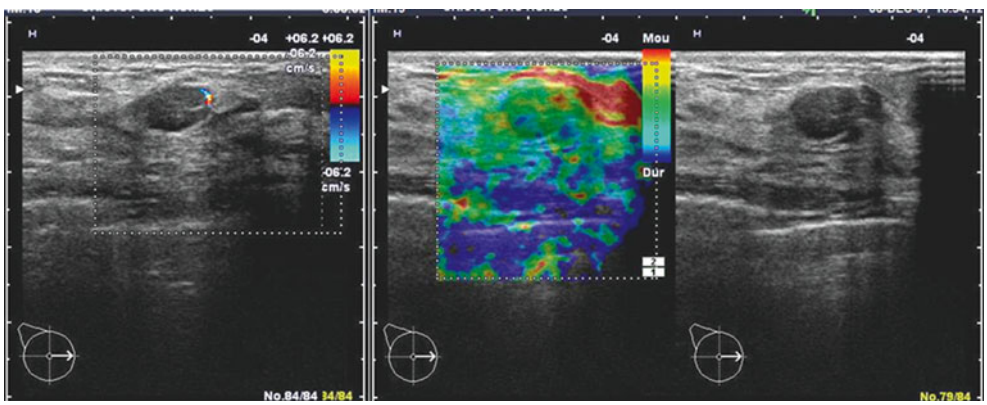

Fig. 4.5 FBU: benign 2D appearances, peripheral unipolar new vasculature, and sonoelastography with the score 2 Ueno for this mass connected to the ductal tree on DE could be considered highly predictive for fibroadenoma (US BI-RADS 2 category). The tumoral development is demonstrated on these scans as a combined process of internal growths (concretion) and accretion of the neighboring lobules

hypoechoic) or by the possibility to differentiate the nonmalignant simple postoperative scar from the local recurrence. Moreover, the most relevant utility of sonoelastography presented by Ueno is the precise visualization in blue color of the nonpalpable intraductal breast carcinoma, which represents unexpected finding. This is the same for the early-stage breast cancer detected by mammography, based only on the visualization of the microcalcifications, without any salient tumoral mass; astonishingly, less than 5 mm dimension tumoral proliferation is easily diagnosed by sonoelastography.

Another important advantage of sonoelastography is the possibility to better visualize the nondefined malignant masses, such as heterogeneous hyperechoic ill-defined infiltrative carcinomas or postoperative local recurrences after breast-conserving surgery, which are difficult to differentiate from the benign extensive scar at mammography or at MRI with enhancement curve analysis.

The most important aspect is that sonoelastography is able to detect the nonpalpable noninvasive carcinomas,

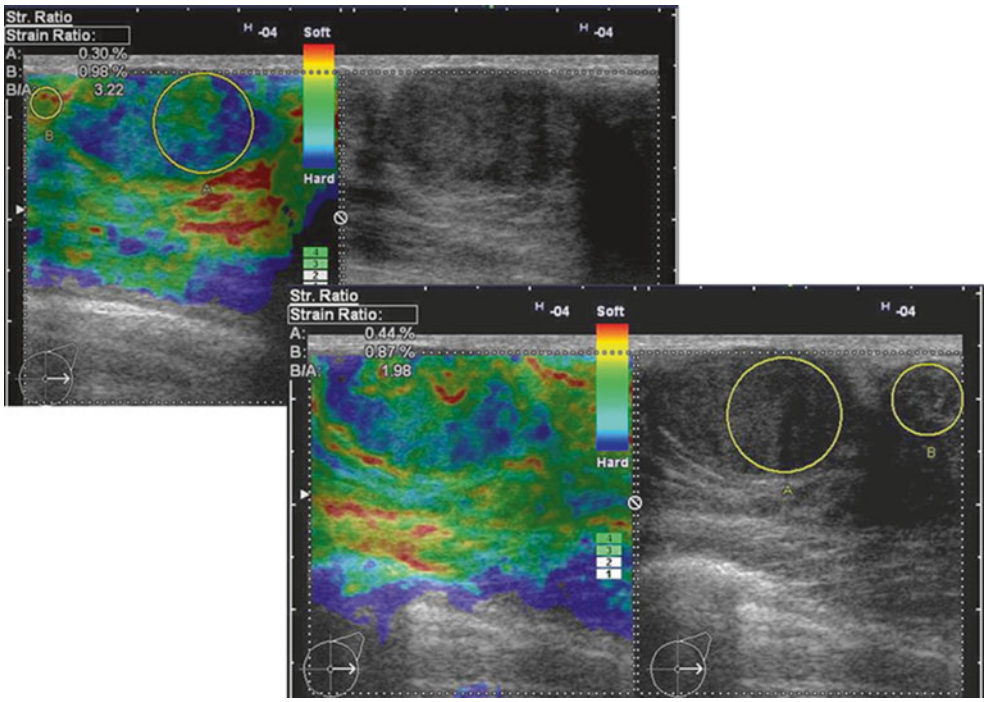

Fig. 4.6 Sonoelastography in the case of a fibroadenoma demonstrates in both elastograms the score 2 Ueno, with low (but different!) FLR, which is due to the different tissue samples

which are difficult to characterize in classical US and difficult and painful to localize by mammographic guidance with harpoon planting or by MRI guidance.

There are some important score assessment rules established by the manufacturer:

1. For scores 3, 4, and 5, we have to make the assessment over the width of the lesion and not its depth.
2. Score 2 is the image that shows mosaic shapes of green within a large area of the lesion.
3. It is hard for the pressure to penetrate deep into the lesion and difficult to extract the signal in the case of poor penetration. In this case, we must not overestimate the elasticity score (but we can change the acoustic window).
4. Blurring in the direction of depth: the faster the compression speed, the more blurring occurs:
   - At the upper part of lesion near the subcutaneous fat
   - At a deeper position at the back of the lesion near to the retromammary fat

   The elastogram must be repeated with the correct technique, to avoid the overestimation diagnosis.
5. Tumor in deep layer of mammary gland must be carefully examined because:
   - It is hard to get sufficient compression for elastography.
   - It is harder to get a good signal (only light pressure should be used).

In this case, the sensitivity of the elastography score is low, and it must be interpreted according to the grayscale and Doppler imaging; most cases from the classical ultrasound are easily interpreted in DE. Sometimes, it is useful to change the acoustic window and to repeat the elastogram in a nonconventional scan, but with the lesion in a more superficial position.

4.6 Role of SE in Nonpalpable Breast Lesions

A real challenge was to evaluate the diagnostic utility of sonoelastography in differentiating benign from malignant nonpalpable breast lesions.

An interesting study by Scaperrotta et al. evaluated 293 BI-RADS 3–5 impalpable breast lesions up to 2 cm in diameter in 278 women, which were examined with B-mode US and with sonoelastography before performing US-guided biopsy. Their conclusion was that the overall performance of sonoelastography was lower than that of US, with sensitivity and specificity of 80 % and 80.9 %, respectively, and 87.4 % for US. Their statistical analysis showed no improvement in the joint use of sonoelastography and US over the use of US alone, whose performance, however, was very high in their study.

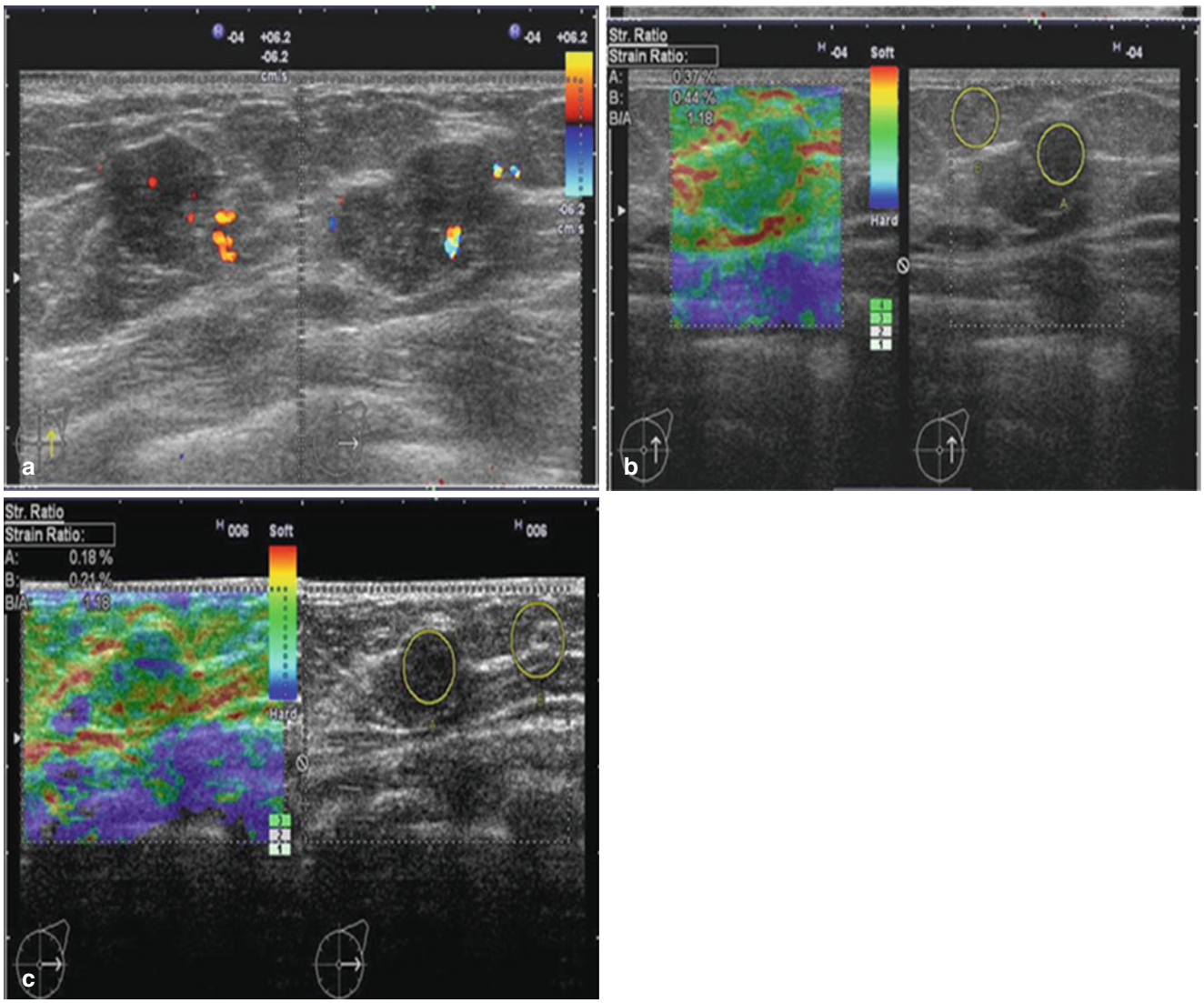

Fig. 4.7 Doppler US illustrates a borderline mass: multilobulated contour and moderate new vasculature with incident angle; however, sonoelastography performed on radial and antiradial scans scored 2 Ueno with low FLR suggesting benign lesion. The final assessment was US BI-RADS 3 category (nodular fibro-micro-cystic dysplasia)

Wherever, they recommend sonoelastography as a simple, fast, and noninvasive diagnostic method that may be a useful aid to US for less experienced radiologists in the assessment of solid nonpalpable breast lesions, especially BI-RADS 3, where specificity was higher (88.7 %) [6]. What should we learn from this study? The authors compared the results of the B-mode US and SE as different methods of imaging diagnosis, while they are parts of a unique technique, we mean the complete US. In the US diagnosis of a lesion, we must combine all the disposable information: the morphological criteria of Stavros and BI-RADS classification on B-mode US, the vasculature assessment of Doppler investigation, and the strain characterization of sonoelastography, all of them being necessary to finalize the diagnosis. The full examination in US is logical, similar to using all the procedures on the mammography, completing the standard examination with complementary views or magnification films. The same full action is achieved in breast MRI, which is not complete without adding the contrast paramagnetic agents and curve enhancement analysis.

The wrong application of sonoelastography is responsible for the discordant published reports and the lack of confidence in some countries with rich technologies; it is expected further that training operators will improve the quality of the examinations and their results. Contrarily to the

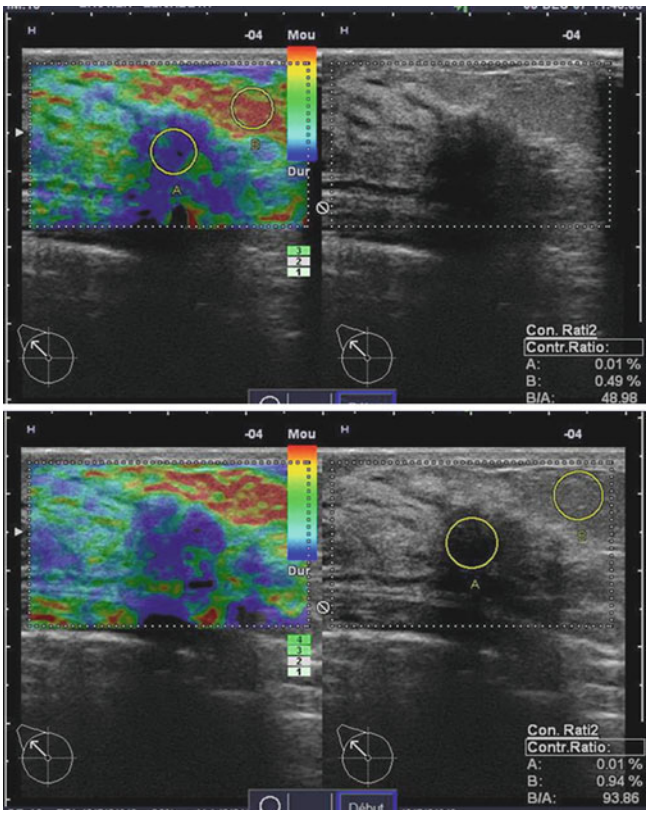

Fig. 4.8 Sonoelastography of a typical malignant lesion at R 10:30 on DE, with large hypoechoic area, irregularly shaped, taller than wide, with angular borders, connected to the ductal tree, and with intense acoustic shadowing. The corresponding area presents a heterogeneous elastogram, predominantly blue colored of score 4 Ueno, with high values on repeated determinations of the FLR 48.98–93.86, concordant for the diagnosis of malignancy (US BI-RADS 4 category if Doppler signal of malignant-type)

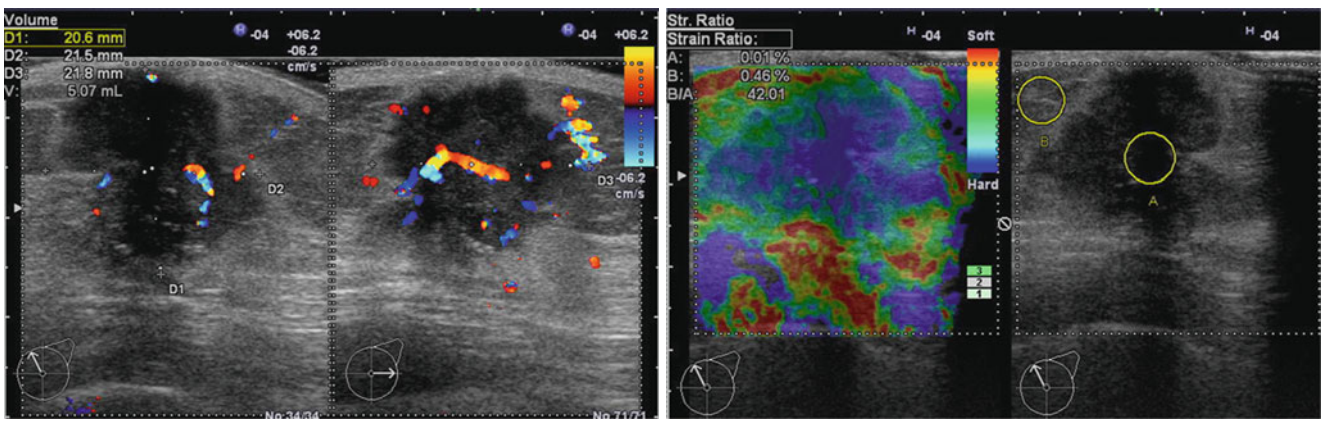

Fig. 4.9 Sonoelastography of typical malignant lesion at Doppler US: low elasticity, mostly intratumoral (*dark blue*) and peritumoral (*light blue*), the halo representing the desmoplastic reaction. The score 5 Ueno is correlated with the US BI-RADS 5 category, the final assessment in FBU

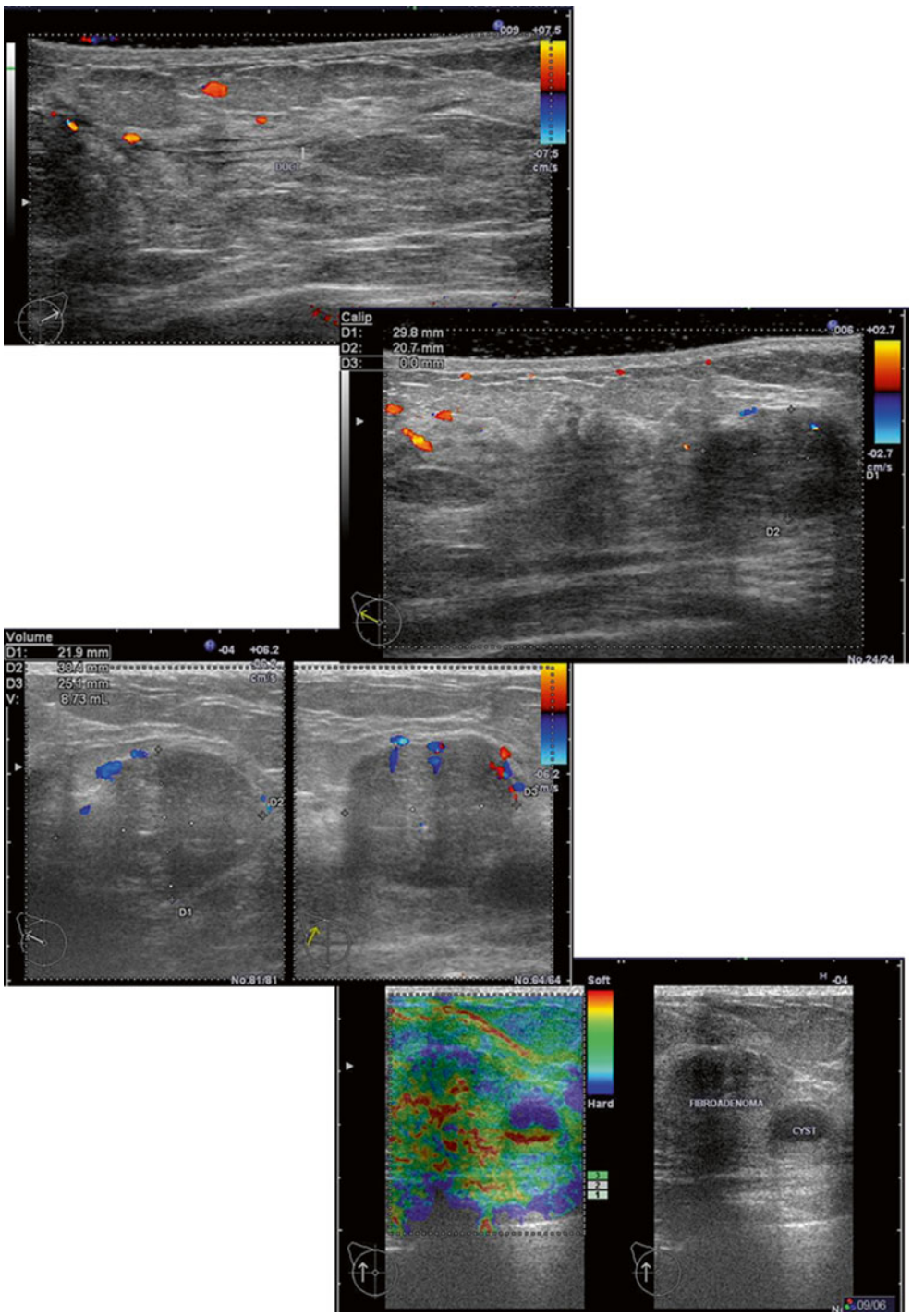

Fig. 4.10 Lactating the breast, with ductal ectasias and hypervascularity: at R 9:30, there is a solid lesion (Stavros criteria) with color Doppler of benign type, suggesting fibroadenoma; the elastogram presents a score 2 Ueno for the solid lesion, associated with a BGR score corresponding to a neighboring cyst. Both lesions are better characterized using all the available tools of US, representing FBU

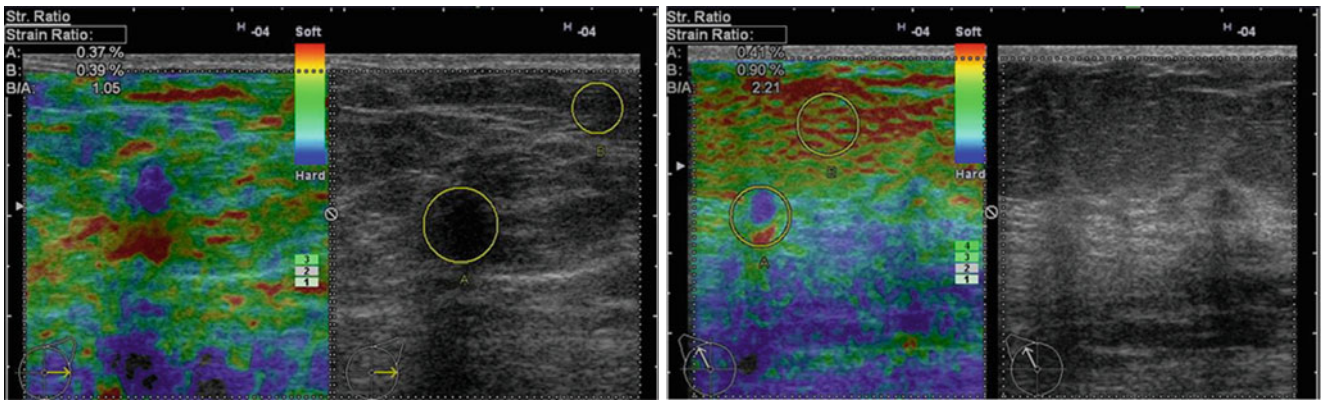

Fig. 4.11 Sonoelastography of pseudomalignant lesions at 2D US, hypoechoic, taller than wide, with irregular borders, and with acoustic shadowing; the elastograms are changing the assessment from 4 to 5 US BI-RADS categories in BI-RADS 2 category. The BGR-summation score is suggesting for fluid content, and the overall FBU diagnosis is fibro-micro-cystic dysplasia located in TDLUs

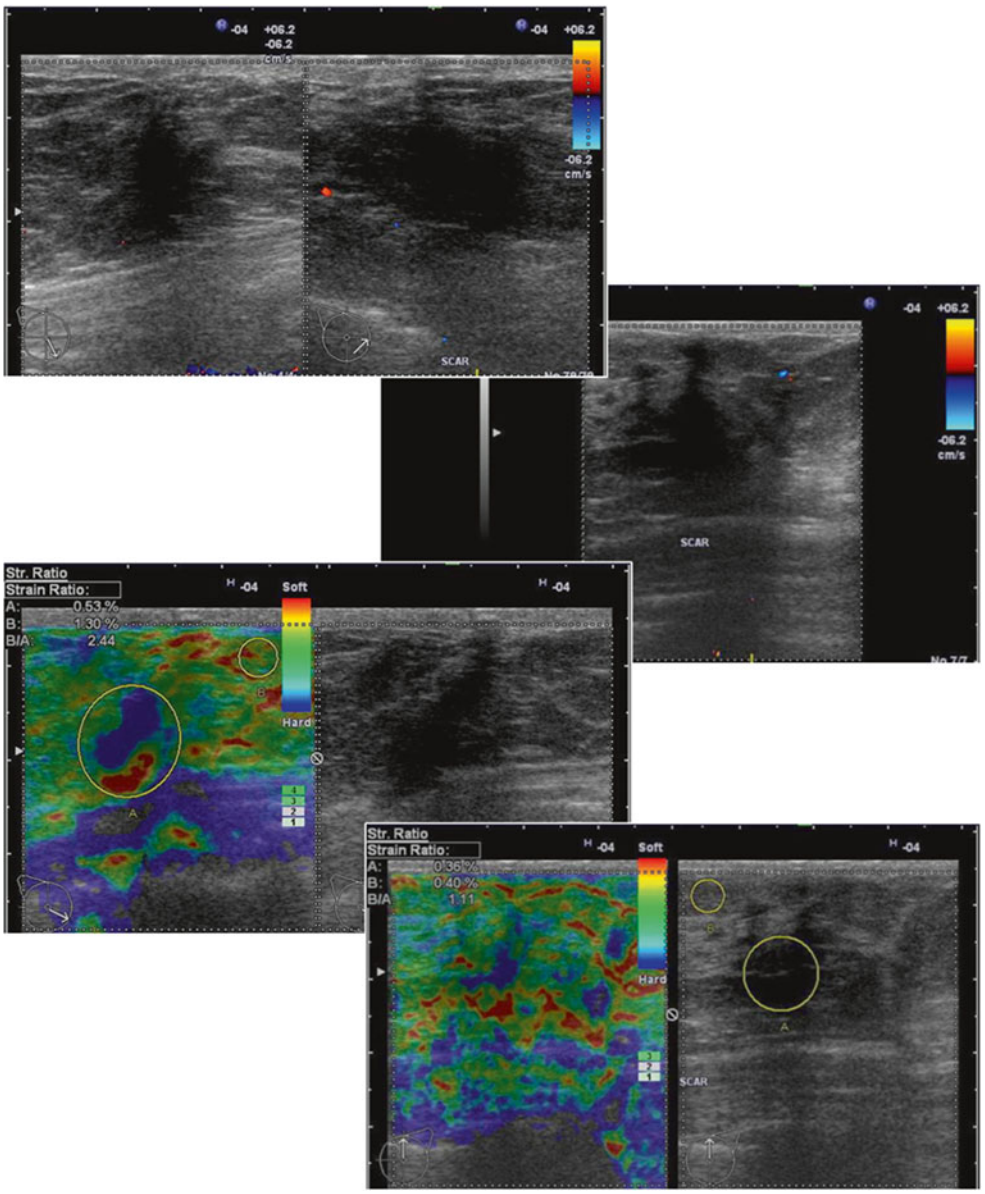

Fig. 4.12 Pseudomalignant aspect at US of this scar in a patient after conservative surgery, but without suspect Doppler signal and with complex BGR score; FBU certifies a benign scar (US BI-RADS 2/3 category), difficult to characterize by mammography, and more expansive examination by MRI

above-presented study, we think sonoelastography is a useful tool in the hand of trained and experienced operators.

Conclusions

Sonoelastography will reduce the diagnostic biopsies in suspect lesions, especially for the BI-RADS 4 category, and the publications estimate that this technique will avoid unnecessary biopsies for 25–40 % cases. The benefit is especially due to the absence of side effects, as compared with vacuum-assisted breast biopsy, which is followed by hematoma in up to 94 % cases after a week and 55 % after three weeks, or fine-needle aspiration biopsy (FNAB) with up to 60 % hematomas or fat necrosis [18].

Sonoelastography alone has low specificity for benign lesions such as fibro-micro-cystic dysplasia and for the scars and chronic inflammatory lesions, but FBU offers a better accuracy compared with MRI. The new concept of FBU will improve the overall results of breast US and of sonoelastography; this is a challenge recommended in diagnosis, screening, and guiding interventional procedures. Sonoelastography presents smaller areas of some benign lesions as compared with grayscale imaging (score 3 Ueno) or greater area in the score 5 Ueno, so it should not be used as a single method of diagnosis.

Moreover, for the malignant lesions with a score 5 Ueno, where sonoelastogram presents larger area including the transitional zone/the halo, there are implications in the conservative surgery, for the correct excision with "safe tumoral margins"; as a benefit, the presence of the light-blue halo avoid false-negative biopsies that omit the center/core of the lesion.

Despite the beginning age of sonoelastography, when there are some criticisms due to the misunderstanding of the technique and heterogeneous devices and techniques of acquisition, the method proved its value and some international guidelines were published [19], with recommendation to correlate this technique with the BI-RADS malignancy probability scale [20]; moreover, it seems sonoelastography is more useful in characterizing the risk of malignancy than the more expansive CEUS.

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