Review of the Techniques and Diagnostic Criteria of Breast Ultrasound Elastography

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1. Introduction

Elastography provides information of tissue hardness, in addition to shape or vascularity, which was obtained with conventional ultrasound. In breast diseases, elasticity score has almost equaled diagnostic performance with the conventional method[1]. However, in clinical practice, Elastography is not used independently but as an additional role for conventional ultrasound. Moreover, there is a problem in the reproducibility of the image, because Elastography images are obtained manually. The techniques and diagnostic criteria of ultrasound Elastography will be discussed here.

2. Simple diagnostic criteria of breast Elastography; Elasticity score

Breast Elastography images are classified into the following 5 imaging patterns (Tsukuba Elasticity Score) compared with the B-mode hypoechoic lesions (Fig. 1).

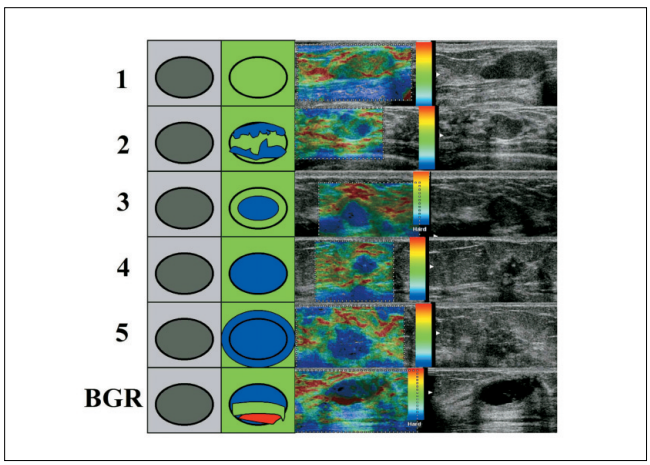

Fig. 1 : Tsukuba Elasticity Score patterns and clinical cases

Score 1: Strain appears in the entire hypoechoic area (the entire lesion is shown in green as is the surrounding normal breast)

Score 2: Strain is not seen in part of the hypoechoic (the lesion is shown as a mosaic of green and blue)

Score 3: Strain appears only in the peripheral areas and not at the center of the hypoechoic area (the center of the lesion is shown in blue with the peripheral areas in green)

Score 4: No strain appears in the entire hypoechoic area (the entire lesion is shown in blue)

Score 5: No strain appears either in the hypoechoic area or surrounding areas (the lesion and the surrounding area are shown in blue)

The possibility of malignancy increases when the score is higher. Sensitivity and specificity become the highest when a score between 3 and 4 is established as the cut-off point for benign and malignancy.

3. Reproducibility of breast Elastography

3.1 Points for maintaining the reproducibility of breast Elastography examination techniques

(1) Establishment of region of interest (ROI)

The Elastography currently used in clinical practice shows the distribution of relative strain. It is necessary to include a sufficient area of surrounding normal gland in the ROI to correctly determine the difference in hardness of the lesion compared with the surrounding area. The recommended ROI, irrespective of the size of a lesion, should extend vertically from the subcutaneous layer to the greater pectoral muscle (not including the rib) and horizontally across the entire width of the screen.

(2) Techniques for obtaining Elastography images

The techniques of examination consist of the following two elements.

(a) Degree of initial compression (the initial intensity of compression by a probe applied to the breast)

When further compression is applied from the position where this B-mode image is clearly shown, it becomes excessive compression for Elastography (Fig. 2a). A high quality elasticity image is obtained with light contact that does not distort the breast (Fig. 2b). When strong initial compression is applied, a false-negative result may be obtained because relations of nonlinear properties of tissue elasticity are changed. Elastography performed by applying appropriate compression shows the pectoral muscle included in the ROI as a uniform blue or the subcutaneous fat layer is shown as stripes of green and red (Fig. 3).

Fig. 2a : Performing Elastography with excessive initial compression

Fig. 2b : Performing Elastography with appropriate initial compression

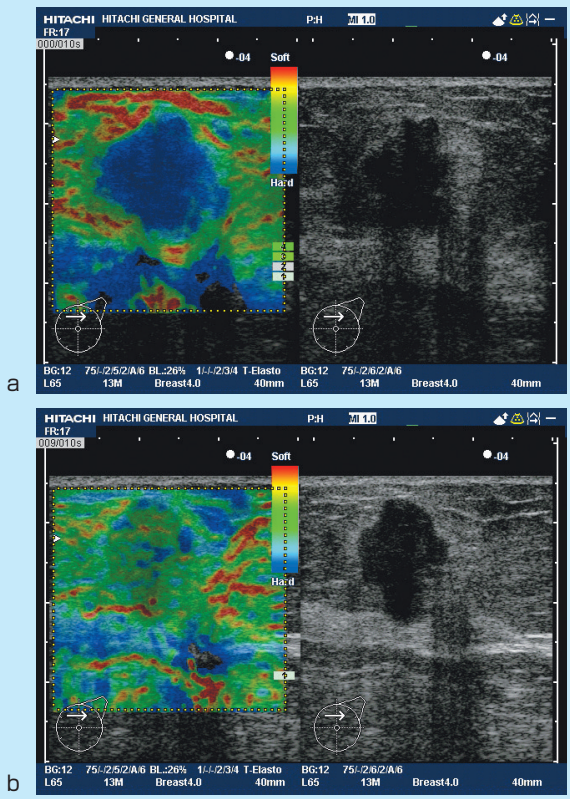

Fig. 3 : 51-year-old female with invasive ductal carcinoma

a: Elastography image obtained with appropriate initial compression (greater pectoral muscle in the ROI is blue) indicating a score of 5

b: Elastography image obtained with excessive initial compression (greater pectoral muscle in the ROI is red) indicating a score of 2

(b) Amplitude and movement speed of a probe

The appropriate vertical amplitude when moving a probe is between 1 and 2 mm. An appropriate speed for vertically moving a probe would be once or twice per second. If a probe is moved too much, it may result in a false-negative diagnosis because the images obtained may indicate “large distortion” due to tracking errors. When the amplitude is too much, assessment of the score differs depending on the framed image used due to the large differences observed when viewing the moving image. In such a case, go back in the cine-memory using a track ball to extract a still image obtained with the lightest compression (the image that a lesion seems to be the most firm) for making a diagnosis.

3.2 Points for maintaining elasticity score assessment reproducibility

(1) Assess score in the horizontal direction

Elasticity images have changed along with vertical movement by compression. Therefore assessment of the score is more accurate in the horizontal direction of a lesion rather than the vertical direction (Fig. 4).

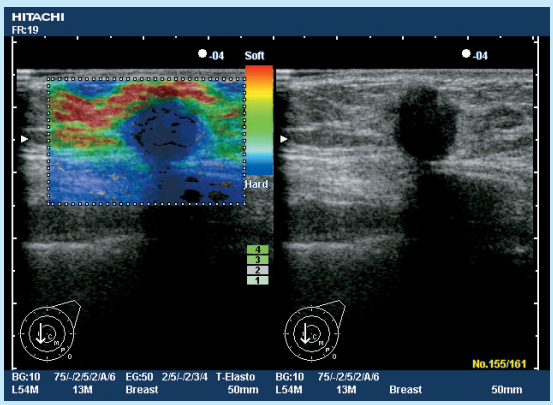

Fig. 4 : 71-year-old female with invasive ductal carcinoma
In this case the score determined in the vertical direction is 3 but in the horizontal direction the score can be judged to be 5.

(2) Precautions when assessing a score of 2

Examiner hesitates occasionally whether to assess the image in which the blue area is clearly predominant but the green areas are partially mixed as a score of 2 or a score of 4 (Fig. 5). A score of 2 is defined as an image with green is mixed to connect from peripheral with a more predominant green area. Even if the diameter of a mass is somewhat large (2 cm or larger) or a deep area lesion is a

hard mass resulting in an image partially dotted with green, they should not be assessed as having a score of 2.

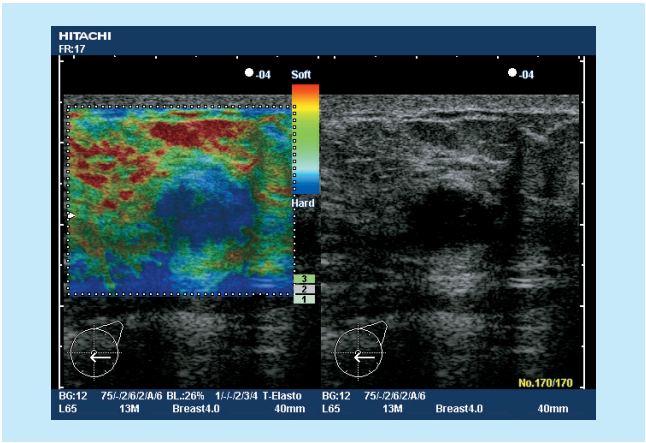

Fig. 5 : 48-year-old female with invasive ductal carcinoma
Although there are some areas of green, because the blue area is clearly larger the elasticity score was determined to be 4.

4. Practical utility of Elastography

Breast disease was diagnosed in 487 patients (the lesions in 320 patients were benign and those in 167 patients were malignant) at Hitachi General Hospital from July 2004 to February 2006 using the EUB-8500 ultrasound system (Hitachi Medical Corporation) with built-in Elastography software. Almost equivalent diagnostic performance with the conventional method was shown for categories 3 and 4 using the elasticity score alone, with sensitivity, specificity and diagnostic accuracy of 88.0%, 83.1% and 84.8% respectively for the conventional method compared to 85.0%, 82.5% and 83.4% respectively for Elastography. One of the advantages of Elastography is that diagnostic accuracy of over 80% is achieved with five simple diagnostic criteria if the operator becomes familiar with the appropriate techniques.

However, diagnosis by Elastography alone is not practical. Elastography is required as a means of assessment to complement the conventional method. The interpretation of the elasticity score as an auxiliary diagnosis differs depending on the shape of the lesion.

(1) Mass image-forming lesions

Mass formation was detected in 381 of the target subjects (benign: 237, malignant: 144), with sensitivity, specificity and diagnostic accuracy of 90.3%, 82.3% and 85.3% respectively using the conventional ultrasound diagnostic method (Table 1). However, 175 (73.8%) of the 237 subjects with benign lesions were diagnosed as category 3 or higher, therefore cytology or core needle biopsy were required to confirm benign. When adopting a score between 3 and 4 as the cut-off point for Elastography, sensitivity, specificity and diagnostic accuracy were 89.6%, 80.2%, and 83.7% respectively (Table 2). Of the subjects with a benign mass, 101 subjects (42.6%), 74 fewer compared with the conventional method, were diagnosed as a score of 3 or lower. No subject had a score of 1 indicating a malignant lesion, and in each of the 5 subjects with a score of 2 indicating malignant lesion, the diameter of the mass was over 25 mm (26-32 mm). When Elastography was performed with the correct technique, almost all mass image-forming lesions under 20 mm in diameter with a score of 1 or 2 could be judged as being benign, suggesting the possibility that Elastography could reduce the need for cytological and histological diagnosis (Fig. 6). Of the subjects diagnosed as a score of 3, the lesions in 54 (84.4%) of them were benign and only 10 subjects (15.6%) were judged to have malig-

Table 1 : Ultrasound categories of mass image-forming lesions

	Category1	Category2	Category3	Category4	Category5
Benign	0	62	133	42	0
Malignant	0	1	13	45	85

Table 2 : Elasticity score for each pathological diagnosis of mass image-forming lesions

	Score1	Score2	Score3	Score4	Score5
Benign	43	93	54	38	9
Fibro adenoma	22	43	25	8	1
Intraductal papilloma	5	6	5	4	0
Phyllodes tumor	0	2	2	3	0
Fibrocystic disease	8	19	7	8	5
Complicated cyst	4	13	14	15	3
Others	4	10	1	0	0
Malignant	0	5	10	31	98
Invasive ductal ca.	0	3	5	21	88
Ductal ca. in situ	0	0	3	7	3
Invasive lobular ca.	0	1	0	0	6
Mucinous ca.	0	0	2	0	0
Medullary ca.	0	1	0	1	0
Tubular ca.	0	0	0	1	0
Others	0	0	0	1	1

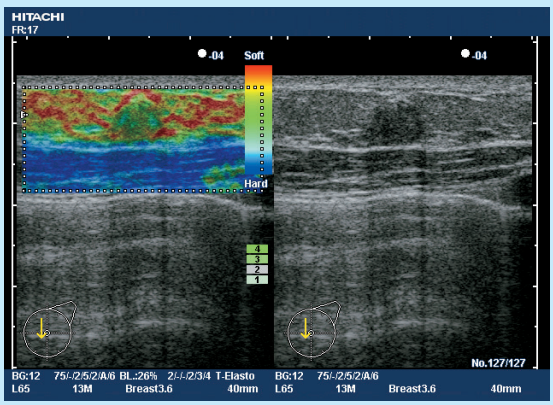

Fig. 6 : 38-year-old female with fibro adenoma
The diagnosis with conventional ultrasound was Category 3 but with a follow-up Elastography examination the score was 1, indicating the extremely high possibility that the lesion was benign. For this case a biopsy verified fibro adenoma but in the future biopsies may eventually become unnecessary for lesions like this.

nant lesions. Although a score of 3 for a lesion is not a positive indication of suspected malignancy, it would be better to perform cytology (Fig. 7).

(2) Non-mass image-forming lesions

When using ultrasound, non-mass image-forming lesions are shown only as a partly mottled, a slightly low-echo area compared with the surrounding breast, or merely as calcification. Non-mass image-forming lesions were diagnosed for 106 (benign in 83 subjects and malignant in 23 subjects) of the targeted subjects, and sensitivity and specificity were 73.9% and 85.5% respectively for conventional ultrasound (Table 3). When assuming a score between 3 and 4 as the cut-off point for Elastography in the same way as for mass image-forming lesions, sensitivity and specificity were 52.2% and 89.1% respectively, with sensitivity lower than that with the conventional method (Table 4). It is therefore dangerous to make a benign or malignant diagnosis simply by assuming that a score between 3 and 4 is the cut-off point. Score of 1 becomes the conclusive evidence of benign in cases with high possibility of a benign as for the conventional method. Some subjects were diagnosed as ductal carcinoma in situ after performing cytological diagnosis because partly mottled areas were showed harder than the adjacent gland (Fig. 8). However in calcified lesion without an obvious low-echoic area, even if it has a score of 1, ductal carcinoma in situ is incontrovertible. In a word, Elastography is useful for pick up suspicious of lesions among non-mass image-forming lesions but cytology or needle biopsy should be considered when malignancy is incontrovertible in the B-mode image or mammography.

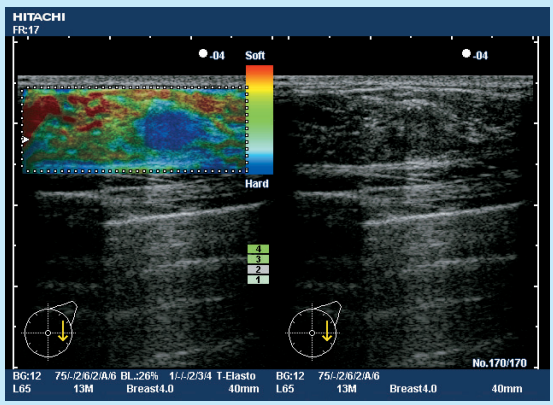

Fig. 7 : 44-year-old female with mucinous carcinoma
B-mode image indicated a lesion similar to that in Fig. 6 but with Elastography the score was 3. Taking into consideration the possibility of malignancy, a needle biopsy was performed and mucinous carcinoma was diagnosed.

Table 3 : Ultrasound categories of non-mass image-forming lesions

	Category1	Category2	Category3	Category4	Category5
Benign	0	12	59	12	0
Malignant	0	0	6	13	4

Table 4 : Elasticity score for each pathological diagnosis of non-mass image-forming lesions

	Score1	Score2	Score3	Score4	Score5
Benign	26	39	9	7	2
Fibrocystic disease	26	30	5	5	1
Intraductal papilloma	0	2	2	0	1
Fibro adenoma	0	1	2	0	0
Complicated cyst	0	2	0	1	0
Mastitis	0	2	0	0	0
Diabetic mastopathy	0	2	0	1	0
Malignant	2	5	3	7	6
Invasive ductal ca.	1	2	2	3	3
Ductal ca. in situ	1	3	1	3	3
Mucinous ca.	0	0	0	1	0

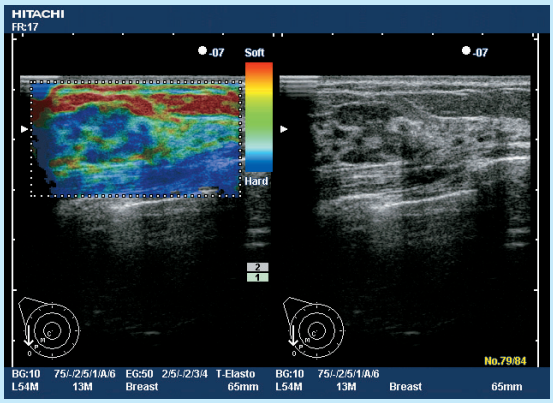

Fig. 8 : 37-year-old female with ductal carcinoma in situ
In the B-mode, a partly mottled low-echo area can be observed. With Elastography, there is blue and green mixed pattern (elasticity score of 2) but since the hardness was clearly different from that of the adjacent gland a needle biopsy was performed. The diagnosis was ductal carcinoma in situ.

5. Conclusion

Ultrasound Elastography is a simple, non-invasive diagnostic method for breast diseases providing diagnostic accuracy comparable with that of the conventional method, but examination techniques should be performed carefully.

The interpretation and role of the elasticity score differ when applied for the diagnosis in mass image-forming or non-mass image-forming lesions. For mass image-forming lesions, scores of 1 and 2 are considered almost always to indicate that the legion is benign. For the diagnosis of non-mass image-forming lesions, the elasticity score is sufficiently valuable for screening for possibly malignant lesions. However, do not exclude the indication of cytology only by the opinion of Elastography.

References

1) Ito A, et al. Breast Disease: Clinical Application of US Elastography for Diagnosis. Radiology 2006; 239:2, 341-350.