European Journal of Radiology 83 (2014) 429–437

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Clinical application of breast elastography: State of the art

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ARTICLE INFO

Article history:
Received 29 April 2013
Accepted 7 May 2013

Keywords:
US-elastography
Breast nodules
Strain elastography
Shear wave elastography

ABSTRACT

Breast elastography is a new sonographic imaging technique for the characterization of focal breast lesions in addition to conventional ultrasonography (US) and mammography. Elastography provides a non-invasive evaluation of the stiffness of a lesion. Two different technical approaches are available for clinical use: free-hand elastography (USE) and shear wave elastography (SWE). Initial results of these techniques in clinical trials suggest that elastography substantially improves the US capability in differentiating benign from malignant breast lesions, thus reducing the number of breast biopsies in benign nodules. This review paper, based on an extensive literature search, highlights the basics of breast elastography, including main technical features, how to do suggestions, limit and pitfalls, and presents the results of major clinical studies.

1. Introduction

Mammography and ultrasonography (US) are commonly used for the characterization of breast masses in order to define the risk of malignancy. Both methods present some limitations. Mammography may often yield false-negative results in dense breast. US is a very sensitive tool in detection, while it has poor specificity in characterization. The different features of the lesion may be evaluated according the BI-RADS criteria [1], which unfortunately generate a significant number of false positive results, leading to an increase in biopsies, with a poor cancer detection rate (10–30%) [2].

Ultrasound elastography has been introduced as a complimentary modality for improving lesion characterization. This technique may assess the stiffness of a lesion by mapping the strain in tissue elements subjected to an external compression. Elasticity is the ability of a tissue to resume the original size and shape after an external deformation (stress), while the strain is the level of change in size or shape after an external compression (stress). The elasticity information from US elastography is encoded in color and superimposed on US images to obtain a clear evaluation of the relationship between the strain and the lesion [3,4].

Elastography is a new technique, with several technological solutions, and its role in clinical practice is not yet well defined. The aim of this paper is to systematically review recent literature on the diagnostic performance of breast US elastography, in order to define its potential in differentiating benign and malignant breast masses.

2. Examination technique

Elastography is a technique for the evaluation of the elasticity of a tissue. Data acquired with elastography are similar to those obtained with manual palpation, but elasticity imaging is more sensitive and less subjective than palpation, because the parenchyma can be displayed and analyzed using dedicated software. Elasticity is the property of a tissue to be deformed by an external force and to resume the original size and shape when the force is removed. Tissue deformation is inversely proportional related to the stiffness of a tissue and the return to basic condition (i.e. response time) is function of the histology. In general fatty tissue is easily deformed while fibrous or cancer tissues return to initial condition more slowly than fat or muscle [5]. Breast elastography can be performed using two different methods: free-hand ultrasound elastography (USE) and shear-wave elastography (SWE), including in the latter the acoustic radiation force impulse technology (ARFI) and the Supersonic shear-wave imaging (SSI), considered an implementation of ARFI technology [6].

Abbreviations: ARFI, Acoustic Radiation Force Impulse; NPV, Negative Predictive Value; PPV, Positive Predictive Value; ROI, Region of Interest; RTE, Real Time Elastography; SR, Strain Ratio; SSI, Supersonic Shear Waves Imaging; SWE, Shear Wave Elastography; US, Conventional Ultrasound; USE, Free Hand Elastography; VTI, Virtual Touch Tissue Imaging; VTQ, Virtual Touch Tissue Quantification.

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http://dx.doi.org/10.1016/j.ejrad.2013.05.007

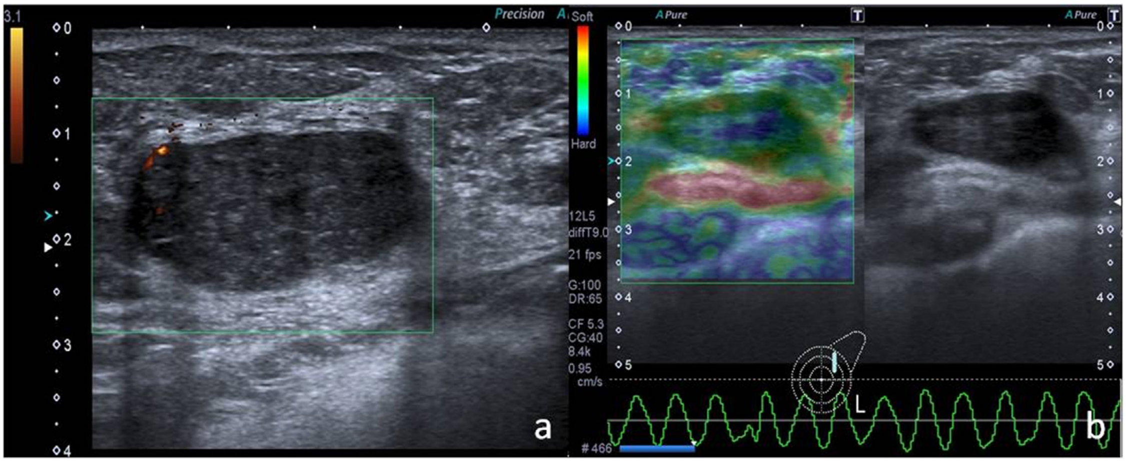

Fig. 1. An hypoechoic nodule with regular and well-defined margins in a 45 year-old patient (a), with two arterial poles at the periphery on the left. The qualitative analysis (b) shows a color map score between 2 and 3 according to Ueno–Itoh classification (due to the blue area in the middle). This pattern refers to medium-high elasticity, Gross pathology demonstrated a benign fibroadenoma.

2.1. Free hand ultrasound elastography (USE)

Free-hand ultrasound or compression elastography ("strain elastography") is based on the application of a compressive force to the breast and on the measurement of the shape-deforming effect, thus providing a value of lesion stiffness compared to that of surrounding tissues. The compression is obtained by applying a slight manual compression/decompression using a conventional transducer. Alternatively the deformation may be determined by respiratory movements. This technique allows only for qualitative and semi-quantitative assessments of a lesion because the force exerted by manual compression is unknown to the equipment, thus allowing only the calculation of the deformability ratio (strain ratio) and not the absolute elasticity [5].

2.1.1. Qualitative assessment in USE

In qualitative assessment breast tissue elasticity is encoded in color map superimposing on B-mode images, similar to color-Doppler (Figs. 1–3).

The elastic image represents a mapping of tissue movement amount that occurred at each location in the breast as a result of deformation. The different colors in the strain images represent different elasticity levels [7]. In one of the first clinical trials for the assessment of breast elastography, Itoh et al. proposed a five-point scoring system to describe the elastic behavior of a lesion [8], assuming the green color as expression of softness and the blue color of stiffness. The scale includes score 1 for soft strain nodule with the entire lesion colored in green; score 2 for lesion with a mosaic pattern of green, red and blue; score 3 for a lesion with blue color in the middle and green in the periphery; score 4 for stiff strain nodule with the entire lesion colored in blue without surrounding area and finally score 5 stiff strain lesion with a blue surrounding area (Fig. 4). In the Itoh et al. experience, based on the examination of 111 nodules (59 benign, 52 malignant, < 30 mm in size), assuming a cut-off point between scores 3 and 4, US elastography had 86.5% sensitivity, 89.8% specificity and 88.3% accuracy. Using a BI-RADS cut-off value between 4 and 5 US reached 71.2% sensitivity, 96.6% specificity and 84.7% accuracy.

As reported by Gong et al. [9], a standardization of the compression exerted on a tissue by the transducer has never been established in different studies. Three years after Itoh' examination, a new qualitative score was proposed (scales 1–4), using the image of the lesion not only before and during compression, but also after parenchymal decompression, in order to be more compatible with the BI-RADS system. Fleury scale included score 1 for lesions presenting the same spectrum of colors as the adjacent breast tissue;

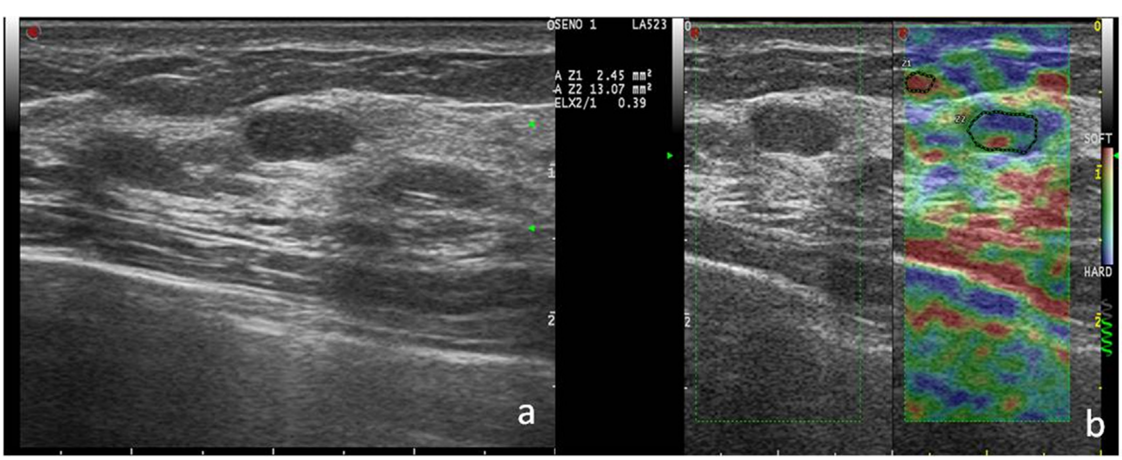

Fig. 2. An hypoechoic nodule with regular and well-defined margins in a 25 year-old patient (a). The qualitative analysis (b) shows a color map score 2 according to Ueno–Itoh classification (a mosaic of different colors as blue, green and red). This pattern refers to medium-high elasticity, Gross pathology demonstrated again a benign fibroadenoma.