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Breast elastography: A literature review

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Abstract Breast elastography is a new sonographic imaging technique which provides information on breast lesions in addition to conventional ultrasonography (US) and mammography. Elastography provides a noninvasive evaluation of the stiffness of a lesion. Today, two technical solutions are available for clinical use: strain elastography and shear wave elastography. Initial evaluations of these techniques in clinical trials suggest that they may substantially improve the possibility of differentiating benign from malignant breast lesions thereby limiting recourse to biopsy and considerably reducing the number of benign breast biopsy diagnoses. This article reviews the basics of this technique, how to perform the examination, image interpretation and the results of major clinical studies. Although elastography is easy to perform, training and technical knowledge are required in order to obtain images permitting a correct interpretation. This paper will highlight the technique and point out common pitfalls.

Sommario L'elastosonografia mammaria è una nuova tecnica di imaging a ultrasuoni che fornisce informazioni aggiuntive sulle lesioni della mammella rispetto all'ecografia e alla mammografia. Consente una valutazione non invasiva della rigidità tessutale di una lesione. Sono attualmente disponibili due soluzioni tecniche per uso clinico: l'elastografia con strain e l'elastografia shear wave. I primi studi clinici di valutazione di queste tecniche suggeriscono che esse possano migliorare la caratterizzazione delle lesioni mammarie differenziando quelle benigne dalle maligne e riducendo in modo sostanziale il numero di biopsie per lesioni benigne. Questo articolo rivisita le basi tecniche, i criteri interpretativi delle immagini, i principali studi clinici e le possibili cause di errore. Per quanto l'elastosonografia sia di facile esecuzione, richiede tuttavia un training e delle conoscenze tecniche adeguate per ottenere immagini correttamente interpretabili.

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Introduction

Mammography and ultrasonography (US) are the diagnostic methods which have shown the highest sensitivity in the detection of breast cancer. However, both methods present some limitations. Mammography performed in dense breasts may often yield false-negative results [1]. US is sensitive in the detection of lesions, but specificity is poor as most solid lesions are benign. In order to obtain an acceptable specificity, various characteristics of the lesions must be evaluated according to the BI-RADS criteria defined by the American College of Radiology (ACR) [2]. Unfortunately, the BI-RADS criteria generate a significant number of false positive results [3]. This limitation leads to an increase in biopsies with a cancer "detection rate" of only 10%—30% [4,5]. Many biopsies are performed in benign lesions causing discomfort to the patients and increased costs.

To overcome these limitations and obtain a more accurate characterization of breast lesions, US elastography was introduced. This technique combines US technology with the basic physical principles of elastography. US elastography is noninvasive and assesses tissue deformability by providing information on the elasticity [6,7]. It is based on the premise that there are significant differences in the mechanical properties of tissues that can be detected by applying an external mechanical force [8,9].

Elastography has proven to be highly specific in the evaluation of lesions situated in various organs: breast, prostate, thyroid, lymph nodes and testes [10—19]. However, this technique is still new, and considering that there are several technological solutions, its role in clinical practice is still to be defined. The aim of this literature review was to clarify the current role of breast elastography.

Elastographic techniques

Elasticity is the property of a body or substance that enables it to be deformed when it is subject to an external force and resume its original shape or size when the force is removed. Different tissues are expected to respond differently according to the specific elastic modulus [22]. Tissue deformation is inversely proportional to the stiffness of the material, and response time (i.e. return to the natural condition) varies as a function of the histotype [23]. In general, adipose tissue is more easily deformed, and fibrous tissue returns to the initial condition more slowly than adipose or muscle tissue [24].

Various tissue compression methods have been proposed in elastography (strain imaging by compression [7], acoustic radiation force impulse (ARFI) [20] and real-time shear velocity (RSV) [21]) which are derived from two technical solutions known as strain elastography and shear wave elastography.

In "strain imaging" by compression the movement of the tissue occurs in the direction of US beam propagation. The most common way to deform the tissue is to apply a slight manual longitudinal compression/decompression using a conventional transducer, or alternatively deformation can be produced by respiratory movements.

The absolute value of the deformation along the longitudinal axis is proportional to the intensity of the compression exerted. However, the force exerted by manual compression is unknown to the equipment and the degree of deformation is calculated exclusively by measuring variations in radiofrequency of the US beam along the axis of the transducer before and after compression. The profile of tissue deformation is converted to an elastic modulus from which an image called elastogram is derived [7]. The impossibility of defining the intensity of the force exerted allows calculation only of the deformability ratio of the various tissues and not the absolute elasticity. For this reason elastography by compression provides only qualitative and not quantitative information.

An alternative solution to the external compression is an acoustic force created by a focused US impulse. This solution is the basis of ARFI and RSV [20,21].

ARFI can be used in two different ways. One is qualitative, as used in strain imaging which employs a short acoustic impulse of high intensity to deform the tissue elements and create a static map (elastogram) of the relative stiffness of the tissues. Another is quantitative, as used in shear wave elastography, which employs a primary acoustic impulse focused on a region of interest where it generates pressure waves in transverse propagation able to deform the tissues. The primary impulse is followed by a few interrogating impulses distributed in the surrounding tissues and designed to calculate the propagation velocity of pressure waves. Propagation velocity and attenuation of the waves are related to the stiffness and visco-elasticity of the tissue. The waves travel faster in stiff tissues than in non-stiff tissues [25]. ARFI quantification provides pressure wave velocity but not spatial distribution. Both the qualitative and quantitative variant of the ARFI method reduce interobserver variability but provide only static information and not dynamic information like elastography by compression.

Unlike ARFI, RSV provides a real-time evaluation of the wave propagation including lateral deformation of the tissues. This is possible because of an original technical solution that generates pressure waves using a conventional transducer and captures the motion by a sequence of thousands of images per second to create a specially designed beamformer [26,27]. Once local propagation velocity of the pressure waves is measured RSV creates a two-dimensional map representing the distribution. The exact values of tissue stiffness expressed in kiloPascals (kPa) can be measured in areas of lesser deformability [28]. ARFI "shear wave" and RSV are quantitative imaging techniques that provide quantitative measures of tissue stiffness with a reduced interobserver variability.

Elastographic imaging

The method which is currently the most widely used in clinical settings is real-time elastography (RTE) which generates "strain imaging" by compression. RTE can be performed using conventional US equipment with dedicated software, and this method assesses the relative elasticity of the tissues in a specific area of interest (the RTE-box)