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The Role of Elastography in Differentiating Benign and Malignant Breast Lesions

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Abstract

Background: The differential diagnosis of benign and malignant breast lesions is a significant challenge in radiology. Traditional imaging modalities such as ultrasonography (USG) and mammography, despite their widespread use, have limitations in accurately differentiating tissues. Elastography, a modern ultrasound imaging technique, enables the assessment of biomechanical properties of tissues, such as hardness and elasticity, offering new possibilities in breast cancer diagnosis.

Objective: The aim of this study is to review the literature on the use of elastography in the diagnosis of breast lesions, with a focus on its effectiveness in differentiating benign and malignant lesions. Different elastographic techniques, their diagnostic parameters and their benefits and limitations compared to traditional imaging modalities are discussed.

Methods: The analysis was based on the available scientific literature published in the last 20 years, searching databases such as PubMed, Scopus and Web of Science. Studies evaluating the effectiveness of elastography (strain and shear-wave) in breast cancer diagnosis and its application in clinical practice were included.

Results and conclusions: Elastography demonstrates high diagnostic efficacy, achieving sensitivity and specificity comparable to or superior to traditional ultrasound. Due to its ability to non-invasively assess tissue hardness, elastography can reduce the number of unnecessary biopsies. However, the literature review indicates some limitations, such as operator dependence and differences in results obtained with different devices. Further studies, especially multi-centre studies, are needed to standardise diagnostic standards.

Keywords: elastography, breast lesions, benign breast lesions, malignant breast lesions, shear-wave elastography, strain elastography, breast cancer diagnosis, ultrasound imaging, diagnostic imaging, breast cancer screening, non-invasive diagnostics, imaging sensitivity, imaging specificity, tissue elasticity, advanced ultrasound techniques

Epidemiology and diagnosis of breast cancer

Breast cancer is one of the most common malignancies in women worldwide. According to the World Health Organisation (WHO), breast cancer accounts for approximately 25% of all cancers. in women [1]. Early detection of breast cancer is crucial for effective treatment and improved prognosis, and diagnosis relies on a variety of imaging techniques. In 2020, an estimated 2.3 million new cases of breast cancer were diagnosed worldwide [1]. In Europe, the cancer accounts for 16.6% of all cancer deaths among women [2]. Breast cancer diagnosis includes both screening methods and clinical diagnosis, and one of the most important challenges is to accurately differentiate between benign and malignant lesions [3].

Importance of early diagnosis and differentiation of benign and malignant lesions

Early detection of breast cancer significantly increases the chances of successful treatment and improved survival rates [4]. An important aspect of diagnosis is the differentiation of benign lesions, such as cysts or adenofibromas, from malignant lesions, thus avoiding unnecessary invasive procedures and reducing diagnostic costs [5].

Standard diagnostic methods

Mammography, ultrasonography [ultrasound] and biopsy are mainly used in the diagnosis of breast cancer. Mammography is considered the standard screening method, especially in women over 40 years of age [6]. However, its effectiveness may be limited in women with dense glandular tissue, leading to difficulties in interpreting the results [7], while ultrasound, although more sensitive in such cases, often leads to false-positive results, resulting in unnecessary biopsies [8]. Ultrasound is widely used as an adjunct to mammography and for women with dense breast glands [9]. Despite its high sensitivity, ultrasound is subjective and depends on the experience of the operator, which affects its accuracy [10]. Biopsy, being the ultimate diagnostic tool, allows definitive confirmation of the nature of the lesion, but is associated with invasiveness and risk of complications [11].

Introduction to elastography

Elastography is a modern imaging technique that assesses the elasticity and hardness of tissues based on their response to pressure [12]. It assesses the stiffness of tissues by measuring their deformability under mechanical force. Tissue stiffness is a key indicator to differentiate benign (soft) lesions from malignant (hard) lesions [13]. This method is based on ultrasonography and allows real-time assessment of the mechanical properties of tissues. There are different types of elastography, including dynamic elastography, static elastography and shear-wave elastography [14]. Shear-wave elastography is particularly valued for its ability to accurately assess tissue hardness, making it very useful in the diagnosis of breast lesions [3].

Use of elastography in the diagnosis of breast lesions

Elastography is increasingly used in the diagnosis of breast lesions, especially in the differentiation of benign and malignant lesions. Studies show that malignant lesions tend to be firmer than healthy tissue, allowing for more accurate localisation and assessment [10]. Elastography is a relatively new method, but it has already proven to be of great value in the assessment of focal breast lesions, especially when combined with ultrasound [6]. Findings indicate that this technique increases the precision of assessing variation in tissue stiffness, which helps to reduce the number of unnecessary biopsies [15]. In comparative studies, elastography has shown greater accuracy in assessing tissue hardness than traditional imaging methods [3].

Dynamic elastography (strain elastography)

Dynamic elastography, also known as strain elastography, uses mechanical compression exerted. by the ultrasound transducer or natural movements of the patient's body and analysis of the resulting deformations [16]. Changes in tissue hardness are assessed by comparing deformations in different areas. This method is particularly useful in differentiating benign and malignant breast lesions [17].

- **Sensitivity and specificity**: According to Gheonea et al (2011), the sensitivity of this method is 79-90% and the specificity is 83-88%. Thus, dynamic elastography effectively identifies malignant lesions while minimising false-positive results [17].
- **Limitations**: The results of this method may depend on the experience of the operator, which can lead to variability in interpretation. Additionally, the limited efficiency for deeper lesions is a significant limiting factor [18].

Static elastography

Static elastography involves the assessment of tissue deformation induced by manual compression.[15] It is a simple and inexpensive method, but more prone to errors due to operator technique [19].

- **Sensitivity and specificity**: A study by Balleyguier et al (2013) found a sensitivity of 70-85% and specificity of 75-80%. Although these results are lower compared to shear-wave elastography, static elastography still remains a useful diagnostic tool in the evaluation of superficial breast lesions [19].
- **Limitations**: Static elastography is less accurate for deep-seated lesions and is more prone to subjective errors due to variations in the amount of pressure applied by the operator [20].

Shear-wave elastography (SWE

Shear-wave elastography (SWE) is an advanced diagnostic method that is based on the generation and analysis of transverse waves [shear waves] in the tissue, allowing quantitative stiffness measurements to be obtained [6]. It is a fully automatic technology, which eliminates the risk of subjective errors [21].

- **Sensitivity and specificity**: Shear-wave elastography (SWE) achieves a sensitivity of 86-98% and a specificity of 81% to 96%, making it one of the most accurate methods for breast cancer diagnosis [6,22]. A multicentre study conducted by Cosgrove et al. on 958 patients showed that SWE significantly improves diagnostic accuracy compared with traditional ultrasound [US] [23]. Due to its precision, this method is particularly well suited for differentiating lesions with ambiguous images on conventional ultrasound [21].
- **Advantages**: Lee et al (2014) showed that SWE allows the correct classification of 92%. of malignant lesions and 87% of benign lesions, highlighting the high predictive value of this technology. In addition, this method allows accurate assessment of the hardness of lesions, which can aid in treatment planning [24].
- **Limitations**: The main barrier is the high cost of the devices and limited availability in less developed medical centres [24].

Use of elastography in the evaluation of benign and malignant lesions

Elastography, regardless of its type, is an effective tool to aid in the diagnosis of breast lesions. The main advantage of this technology is its ability to differentiate lesions based on their hardness, reducing the need for diagnostic biopsies [25].

- **Diagnostic efficacy**: A study by Skerl et al (2011) shows that dynamic elastography reduced the number of unnecessary biopsies by 27%, while maintaining high diagnostic sensitivity [25].
- **Summary of effectiveness**: SWE has the highest sensitivity and specificity among elastographic methods. Although dynamic and static elastography offer slightly lower precision, they remain valuable diagnostic tools in less advanced medical centres [24].

Comparison of elastography with other imaging modalities

Compared to mammography, which has limited sensitivity in women with dense breast tissue, elastography has a higher efficiency in differentiating lesions. While mammography has a sensitivity of approximately 70-80%, SWE elastography exceeds this value, reaching up to 95% in certain patient groups [7]. Compared to magnetic resonance imaging (MRI), elastography has advantages in terms of cost and availability. Although MRI is a very accurate imaging modality, elastography offers a comparable ability to differentiate malignant lesions, especially for small or superficially located lesions [26]. The use of elastography in combination with traditional ultrasound offers synergistic results. In clinical studies, the combination of these techniques allows for a significant improvement in diagnostic results, achieving a sensitivity and specificity of more than 90% [27].

Precision of elastography in the detection of malignant lesions

The precision of elastography in the assessment of malignant lesions is due to its ability to quantitatively measure tissue stiffness. Malignant lesions tend to be stiffer compared to benign lesions, which is reflected in elastography results [13]. A study by Barr and Zhang showed that SWE elastography achieves very high performance in differentiating between adenocarcinomas and invasive carcinomas, with areas under the ROC curve (AUC) of 0.95 [28]. Due to its precision, elastography also allows better planning of targeted biopsies, reducing the number of diagnostic procedures and minimising patient burden [29]. Findings suggest that elastography may be particularly useful in the diagnosis of ductal carcinoma in situ (DCIS), which often remains invisible by traditional imaging methods [23].

Advantages

Elastography offers a number of advantages in the diagnosis of breast lesions. It is non-invasive, does not require the use of radiation and at the same time provides detailed information about tissue characteristics [22]. With elastography, it is possible to reduce the number of biopsies, as the technique can pinpoint areas with a high probability of malignancy [10]. It does not require the use of contrast, which increases its safety [30]. In clinical studies, elastography, especially shear-wave elastography, has been shown to have a high sensitivity and specificity in differentiating between benign and malignant lesions, exceeding 90% [31].

Elastography enables the assessment of tissue elasticity, which allows the differentiation of benign from malignant lesions without the need for invasive biopsies in many cases [28,3]. Compared to traditional ultrasound, elastography offers higher precision in assessing the nature of breast lesions and is able to detect malignant lesions even in difficult-to-diagnose tissues such as high-density breasts [23]. The shear-wave elastography (SWE) technique additionally provides quantitative information on tissue stiffness, which increases the reproducibility of results and improves diagnostic accuracy [9]. In addition, elastography can be used in real time, allowing dynamic assessment of breast changes. [12]

Limitations of elastography in practice

Despite its many advantages, elastography also has its limitations. For example, results may depend on the experience of the operator and the equipment used, which affects the consistency and reliability of the results [12,17]. For lesions located in deeper tissue layers or close to the chest wall, the diagnostic accuracy of elastography may be reduced [32]. Elastography may be less effective for lesions of small size or when access to the lesion is difficult [33]. In addition, elastography is not always effective in the assessment of cystic lesions, which may falsely indicate high hardness [20].

Factors influencing results

The results of elastography are influenced by a number of technical and biological factors. Technical factors include the camera settings, the methodology used and the pressure applied during the test [34]. Biological factors, such as breast density, presence of scarring or inflammation, can also affect the tissue stiffness measurements obtained [19]. A major limitation is also the lack of uniform criteria for assessing the results in different centres, which makes it difficult to standardise the technique [18].

State-of-the-art elastographic technology

As an advanced medical imaging technique, elastography is constantly evolving with innovations. to improve diagnostic accuracy and patient comfort [23]. One of the most recent developments is shear-wave elastography (SWE), which allows real-time quantitative assessment of tissue stiffness [23]. Studies have shown that SWE significantly improves specificity in the differentiation of benign and malignant breast lesions, reducing the number of unnecessary biopsies [23]. Another innovative approach is magnetic resonance elastography (MRE), which allows a three-dimensional assessment of tissue elasticity [35]. MRE is particularly promising in the assessment of deep breast lesions and in cases where traditional imaging methods are insufficient [35]. The integration of artificial intelligence (AI) with elastographic techniques represents a further step towards increasing diagnostic accuracy [36]. AI algorithms can analyse elastographic images, identifying subtle differences in tissue stiffness, which can lead to earlier detection of cancerous lesions [36].

Potential directions for the development of elastography in breast cancer diagnosis

The future of elastography in breast cancer diagnosis involves further development of the technology and its integration with other imaging modalities [9]. One direction is to combine elastography with breast tomosynthesis, which may increase sensitivity and specificity in detecting malignant lesions [37]. The development of portable and more accessible elastographic devices may enable wider use of this technology, especially in regions with limited access to advanced diagnostic imaging [38]. This approach may contribute to earlier detection of breast cancer and improved treatment outcomes [38]. Further research into the biological basis of tumour tissue stiffness may lead to the identification of new biomarkers to aid personalisation of therapy and monitoring of treatment response [39].

The future of elastography in diagnosis

Developments in elastographic technology are opening up new possibilities in breast cancer diagnosis. The introduction of advanced quantitative methods, such as 3D shear-wave elastography, and the integration of elastography with other imaging techniques, such as CT or MRI, could significantly increase diagnostic accuracy and versatility [13]. The future of elastography may also include the use of artificial intelligence (AI) in the analysis of elastography data, which could automate the diagnostic process and reduce the dependence of results on the operator [40]. Further clinical trials are needed to assess the long-term effectiveness of these technologies and their impact on patient outcomes [23].

Conclusions

Elastography, with its ability to assess tissue hardness, is a promising tool in the diagnosis of breast lesions, particularly in the context of differentiating between benign and malignant lesions. A review of available studies has shown that elastography, including shear-wave elastography (SWE) technology, offers high sensitivity and specificity in the evaluation of breast cancers, and its use reduces the number of unnecessary biopsies and speeds up the diagnostic process. Technologies such as 3D elastography and the integration of elastography with artificial intelligence algorithms can further improve diagnostic accuracy, making it more precise and less prone to operator error. To summarise the main findings, elastography shows great value in the differentiation of breast lesions, especially in cases where traditional imaging modalities such as mammography or ultrasound may be less effective. It is particularly helpful in assessing tissue hardness, which enables the identification of suspicious malignant lesions. The predictive values of elastography, such as sensitivity and specificity, continue to improve with modern technology, contributing to better diagnostic accuracy. Elastography also has great potential in the monitoring of oncology therapies, especially in the assessment of treatment response in breast cancer patients. It can be a helpful tool in more rapidly detecting changes in breast tissue structure that may suggest disease recurrence or resistance to treatment. Recommendations for the use of elastography in clinical practice Based on the results of the literature review, elastography should be considered as an integral part of diagnostic imaging in the evaluation of breast lesions. Its use may facilitate the detection of tumours at an early stage, improving diagnostic efficiency. It is recommended that it be incorporated into routine diagnostic management, especially in cases that are difficult to diagnose unequivocally using traditional methods. Further research and development of elastographic technology is needed to increase the precision of results, minimise errors associated with interpretation and enable wider use of elastography in the evaluation of breast tumours. It is also necessary to implement standards for the use of elastography to ensure its uniformity and high quality of results across all medical facilities.

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