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Analysis of the Value of Breast Ultrasound Elastography in Differentiating Benign and Malignant Masses

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Abstract: This paper analyzes the value of breast ultrasound elastography in differentiating benign and malignant masses. The principles, development, and current applications of this technology are introduced. The characteristics of benign and malignant masses are explained in detail, and the methods used in elastography to differentiate them, including elasticity scoring and area ratio methods, are described. By comparing the results with pathological findings and other studies, the accuracy of the technology is analyzed, along with its advantages such as compensating for the limitations of conventional ultrasound, lack of radiation damage, and providing additional diagnostic information. Finally, the value of this technology is summarized, and its future prospects are discussed.

Keywords: Breast ultrasound elastography; Benign and malignant masses; Value analysis

Introduction:

Breast diseases are common health problems among women, with the differentiation between benign and malignant masses being critical for treatment decisions and prognostic judgments. In recent years, the incidence of breast diseases has increased annually, and the early detection and treatment of breast masses have become increasingly important. Conventional ultrasound can only provide a preliminary diagnosis of the nature of breast tumors but cannot fully distinguish between benign and malignant masses. As an emerging ultrasound technique, elastography reveals the elastic characteristics of breast masses from a completely new perspective. By evaluating tissue stiffness, it offers a novel approach for differentiating benign and malignant breast tumors.

1. Principles of Breast Ultrasound Elastography

Ultrasound elastography is a technique that uses ultrasound to stimulate tissues, extract parameters related to tissue elasticity, and display these parameters through imaging. The principle of this technique is based on the fact that soft tissues deform more easily than hard tissues when subjected to pressure. The radiofrequency signals generated by the deformation of tissues are analyzed and processed using cross-correlation techniques to obtain various elasticity coefficients representing the strain distribution within the tissue. The hardness of the detected lesion is then visually expressed through grayscale or color-coded images.

In recent years, this technology has been widely applied in clinical settings, particularly in the study of thyroid, breast, and liver diseases. The stiffness of tissues is closely related to the benign or malignant nature of masses, with malignant masses typically being stiffer than benign ones.

The basic principle of ultrasound elastography is that different tissues exhibit different elastic coefficients under the same external force, leading to varying degrees of strain. Tissues with a higher elasticity coefficient undergo less strain, while those with a lower elasticity coefficient undergo more strain. In other words, softer normal tissue deforms more than harder tumor tissue. This technique takes advantage of the differences in elasticity between tumor tissue (and other affected areas) and surrounding normal tissue. By applying pressure or alternating vibrations to the lesion during the examination, varying degrees of strain are induced, allowing for differentiation of the elasticity of the affected tissue. This provides a diagnostic basis for distinguishing between benign and malignant lesions.

2. Characteristics of Benign and Malignant Breast Masses

2.1 Characteristics of Benign Masses

(1) Benign masses typically grow at a slow rate. The growth of benign masses is generally gradual and does not increase rapidly over a short period. For example, benign breast masses may remain stable for several years, even up to ten or more years, with little to no noticeable change. Breast cancer masses are highly variable in terms of growth, and those that grow very slowly or cease growing after years of observation are often benign tumors, such as fibroadenomas, breast adenomas, lipomas, or fibrocystic changes.

(2) The mass is usually smooth and easily movable. Benign masses often exhibit a regular shape with smooth edges, clearly demarcated from surrounding tissues, and are generally easy to move. Benign breast masses are typically oval or round, firm in texture, with well-defined borders, good mobility, and can be either single or multiple. The surface of these masses is often smooth and they are frequently multiple. Benign calcifications are typically found in the stroma and tend to be sparse, scattered, uneven, and of various shapes, more than 5 per cm^2, and located within the mass.

(3) Lymph node enlargement is generally absent. Benign masses typically do not cause lymph node enlargement. In cases where the benign mass is associated with breast pain, lymph node metastasis is not common. For benign breast nodules, there is no invasiveness to surrounding tissues, and patients often do not exhibit significant symptoms, meaning lymph node enlargement is unlikely. Benign breast nodules generally do not lead to lymph node enlargement. Benign tumors are usually not associated with lymph node enlargement, though occasional pain may occur. Additionally, benign tumors do not typically cause thickening of surrounding blood vessels; vascular changes are usually due to compression. The mass compresses or displaces surrounding tissue, with the local glandular structure remaining clear.

2.2 Characteristics of Malignant Masses

(1) Growth Rate: Malignant masses tend to grow rapidly, with tumor cell proliferation unrestricted. Malignant masses grow invasively, and various types of breast cancer tumors, such as invasive ductal carcinoma and medullary carcinoma, exhibit rapid growth. While growth rate can help assess the degree of malignancy, it cannot fully determine whether a breast tumor is benign or malignant. Additionally, the growth rates of different types of malignant breast cancers vary. For example, Luminal-type tumors (ER-positive and HER-2 negative) grow more slowly, while triple-negative breast cancer (TNBC) and HER-2 positive cancers typically grow faster. Younger patients with malignant masses often experience faster growth, while older patients may experience slower growth.

(2) Morphological Features: The mass has a relatively hard texture, and there are spiculated or burr-like features on its edge. The shape of a malignant mass is irregular, with an unsmooth edge and spiculated protrusions. From the perspective of the differentiating points between benign and malignant breast tumors, malignant tumors often present as lobulated, stellate or spiculated, which is caused by the infiltrative growth of the cancer into the surrounding tissues. On the X-ray film, malignant tumors have the characteristic that they feel larger upon palpation while appearing smaller on the image, and the mass shadow shown on the X-ray film is usually about half of that detected by palpation.

(3) Lymph Node Involvement: Lymph nodes

may become enlarged. Malignant breast tumors are commonly associated with enlargement of axillary lymph nodes. As the tumor progresses, cancer cells may metastasize to the lymph nodes, leading to reactive hyperplasia and enlargement. In severe cases, ipsilateral axillary lymph node enlargement may also be present. For patients with bloody nipple discharge or recurring eczematous skin changes in the nipple-areola area, axillary lymph node enlargement may also be observed. Some patients may not present with a palpable mass initially, but may have calcifications detected on mammography as the first sign. For example, in cases of acute mastitis, inflammation may lead to axillary lymph node enlargement, though this differs from lymph node enlargement caused by malignant tumors. Depending on the patient's specific condition, surgical removal of the axillary lymph nodes (sentinel lymph nodes) can be performed for pathological examination to determine the tumor stage. Based on the staging results, an appropriate surgical approach can be selected for the treatment of breast cancer. After surgery, depending on the tumor subtype, radiotherapy or chemotherapy regimens may be chosen to complement the surgery and eradicate tumor cells.

3. Methods for Differentiating Benign and Malignant Masses Using Ultrasound Elastography

3.1 Elasticity Scoring Criteria

The scoring criteria for ultrasound elastography usually adopt the five-point method, which is of great significance for differentiating the benign and malignant breast masses. The following is a detailed introduction to the five-point method:

(1) Introduction to the Five-point Method

The five-point method of ultrasound elastography divides the elastic characteristics of breast masses into five grades from 1 to 5 points. The higher the score, the greater the possibility of malignancy of the mass. This scoring method provides an intuitive basis for doctors to judge the nature of the mass by evaluating the hardness of the mass.

In practical applications, doctors can determine the score according to the color distribution of the mass in the ultrasound elastography image. For example, if the interior of the lesion is combined or not combined with green, and the lesion and its surrounding area are blue, it is scored as 5 points; if there is a little green inside the lesion or the whole is blue, it is scored as 4 points; if the proportion of blue and green inside the lesion is equal, it is scored as 3 points; if the periphery of the lesion is green and the interior is blue, it is scored as 2 points; if the lesion is basically or completely green, it is scored as 1 point.

(2) Meanings of Each Score

A score of 1 indicates normal breast tissue, that is, the whole or most of the breast is soft and elastic, and there are no nodules or masses. This means that in the ultrasound elastography image, the breast tissue is basically or completely green.

A score of 2 usually indicates that nodules or masses appear locally in the breast, and the texture of the local lesion site is slightly tough while the surrounding tissues are soft and elastic. In the image, it is manifested as the periphery of the lesion being green and the interior being blue.

A score of 3 may correspond to larger breast nodules or more severe breast hyperplasia, which is generally benign. At this time, the proportion of blue and green inside the lesion is equal.

A score of 4 indicates that the lesion site and the surrounding tissues become hardened, and the lesion site is even harder, suggesting the possibility of malignancy of the mass. In the image, there is a little green inside the lesion or the whole is blue.

A score of 5 represents a highly malignant tumor, and the texture of the lesion site and the surrounding breast tissues is relatively hard. In the ultrasound elastography image, the interior of the lesion is combined or not combined with green, and the lesion and its surrounding area are blue.

3.2 Area Ratio Method

(1) Measurement Method

The area ratio measurement of breast masses in elastography mode versus grayscale mode is typically performed using a manual tracing method. The procedure involves manually outlining the contour of the mass on both elastography and two-dimensional (2D) grayscale images to determine its area. During the elastography examination, the physician can clearly observe the performance of the breast mass in different modes. In elastography images, the stiffness characteristics of the mass are reflected, while the grayscale 2D image shows the shape and structure of the mass. By measuring the areas of the mass in both image types, an area ratio is calculated, which is of significant value in determining whether a breast mass is benign or malignant.

(2) Benign and Malignant Cut-off Analysis

The cut-off value for using the area ratio to differentiate between benign and malignant breast masses has been established through extensive clinical research and practice. Generally, if the area ratio is above 1.8, the mass is considered malignant; if it is below 1.8, the mass is considered benign. For example, in a study of 410 patient cases involving breast mass differentiation using ultrasound elastography, an area ratio of 1.8 was found to provide the best sensitivity and specificity for diagnosing malignant masses. This value has been adopted as the optimal threshold for determining the malignancy of a breast mass. In another study exploring the application of ultrasound elastography for differentiating benign and malignant breast masses, a cut-off area ratio of ⩾ 1.8 was used to define malignancy, while < 1.8 was considered benign. In this study, the sensitivity, specificity, and accuracy of diagnosing malignant breast tumors using this cut-off were 77.5%, 91.1%, and 86.9%, respectively. Moreover, when comparing the area ratio in ultrasound elastography and conventional ultrasound for mass diagnosis, a ratio of 1.5 was found to be indicative of malignancy. In this case, the sensitivity, specificity, and accuracy of ultrasound elastography for diagnosing malignant breast masses were 85.4%, 87.3%, and 86.7%, respectively. These studies underscore the critical role of the area ratio method in distinguishing between benign and malignant breast masses.

4. Analysis of the Value of Ultrasound Elastography

4.1 Accuracy

(1) Comparison with Pathological Examination Results

One of the most important methods for evaluating the accuracy of ultrasound elastography is comparing its diagnostic results with those of surgical pathological examinations. Numerous studies have shown that ultrasound elastography provides high accuracy, sensitivity, and specificity in differentiating between benign and malignant breast masses. For example, a study conducted at Beihai Hospital in Yantai City, involving 98 patients with 113 confirmed breast tumors, reported that ultrasound elastography had a sensitivity of 88.37%, specificity of 98.57%, and accuracy of 94.69%. Furthermore, in a comparison of ultrasound elastography and pathological results for diagnosing breast masses, the UE (Ultrasound Elastography) score showed sensitivity, specificity, and accuracy of 82.5%, 90.4%, and 88.3%, respectively. These results clearly demonstrate a high level of consistency between ultrasound elastography and pathological examination findings.

The high accuracy of ultrasound elastography can be attributed to its ability to accurately reflect tissue stiffness, a feature that is closely linked to the benign or malignant nature of a mass. Malignant masses are typically harder than benign ones, and by assessing the elasticity characteristics of the mass, ultrasound elastography provides a more reliable diagnostic foundation for doctors.

(2) Comparison of Different Research Results

The accuracy of ultrasound elastography in differentiating between benign and malignant breast masses varies somewhat across different studies. This variation can be attributed to several factors, including the selection of research subjects, the performance of the equipment, and the experience of the operators.

4.2 Analysis of Advantages

(1) Overcoming the Limitations of Conventional Ultrasound

Ultrasound elastography addresses the limitations of conventional ultrasound in differentiating between benign and malignant breast masses. Conventional ultrasound may not provide clear images of dense breast tissue, making it difficult to accurately identify masses within dense breasts. In contrast, ultrasound elastography can more clearly display such masses. For instance, in patients with dense breasts, conventional ultrasound may struggle to accurately assess the nature of the mass, but ultrasound elastography allows for clear observation of the mass's elasticity characteristics, providing a more reliable diagnostic basis for clinicians.

(2) No Radiation Exposure

Ultrasound elastography is non-invasive, painless, and free from radiation, making it safe for repeated use. This feature makes the technology suitable for breast examinations across all age groups, including children, pregnant women, and the elderly. Unlike CT scans or mammograms, which expose patients to radiation, ultrasound elastography does not pose any radiation risk to the patient's body, ensuring a safer diagnostic alternative. For example, during pregnancy and breastfeeding, ultrasound elastography allows for accurate diagnosis of breast masses without risking harm to the fetus or infant.

(3) Providing Additional Information

In addition to assessing the benign or malignant nature of a mass, ultrasound elastography can also evaluate the presence of metastatic lymph nodes in the axilla or supraclavicular regions on the same side of the breast. This additional diagnostic capability provides doctors with more comprehensive information about the patient's condition, aiding in the development of more precise treatment plans. For example, in patients with malignant breast tumors, ultrasound elastography can promptly detect axillary lymph node enlargement, which may indicate lymph node metastasis, thus guiding the choice of surgical approach and subsequent treatments. Moreover, the technology can also be used to assess other organs, such as the liver, for metastatic lesions, offering further insight into the severity of the patient's disease.

Conclusion

Breast ultrasound elastography demonstrates exceptional value and broad application prospects in distinguishing between benign and malignant breast masses. With its unique principles and techniques, such as the elasticity scoring system and area ratio method, it provides reliable support for clinical diagnosis. Compared to traditional diagnostic methods, ultrasound elastography excels in accuracy, effectively compensates for the limitations of conventional ultrasound, and poses no radiation risk. It is repeatable, minimizing both the psychological and physical burden on patients, making it a valuable tool in the early diagnosis and management of breast diseases.

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