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Ultrasonic Diagnosis of Breast Tumors

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Abstract: Breast cancer is a malignant tumor caused by genetic mutations, which induced by various carcinogenic factors, in the epithelial cells of the terminal ductal lobule units of the breast. These mutations allow cancer cells to proliferate indefinitely, leading to a large, disordered accumulation of cancer cells that continuously infiltrate surrounding tissues. During the proliferation of malignant tumor cells, they release Vascular Endothelial Growth Factor (VEGF), which stimulates the neovascularization within the tumor. These neovascularization are usually micro-vessels with diameters less than 200 micrometers. The formation of neonatal vessels plays a crucial role in the growth, infiltration, and metastasis of tumors and appears earlier than morphological changes in the tumor. Therefore, early detection of tumor neovascularization is an important basis for the early diagnosis of malignant tumors. Conventional imaging methods are primarily based on morphological changes in breast tumors. Although color Doppler ultrasound can observe the distribution, deformation, flow rate, and resistance index of larger vessels within the tumor lesion, it is less effective in displaying low-speed micro-vessels. To address this gap, Contrast-Enhanced Ultrasound (CEUS) technology was developed. CEUS technology enhances the contrast between blood and tissue using a contrast agent, highlighting the blood perfusion pattern and clearly showing the distribution and path of vessels within the lesion. This is considered a significant revolution in the history of ultrasound, providing a powerful tool for the detection of neovascularization in tumors.

Keywords: Breast mass; Contrast-Enhanced ultrasound; Sound image diagnosis

Introduction

Currently, the study of contrast-enhanced ultrasound (CEUS) for liver tumors is relatively mature internationally, and its preliminary application in clinical settings has achieved satisfactory results. However, due to the superficial location and relatively poor blood supply of the breast, the technical requirements for contrast imaging are high. Research on breast contrast imaging is still in the exploratory stage and has not yet established unified diagnostic standards. This article begins by examining the sonographic features post-contrast imaging of breast lesions, including lesion enhancement intensity, contrast agent enhancement patterns, post-contrast tumor boundaries, distribution of the contrast agent, peripheral penetrating or radial enhancing vessels around the tumor, and perfusion defects within the lesion. It concludes that contrast-enhanced ultrasound technology is a non-invasive technique capable of clearly displaying the vascular distribution and blood perfusion within lesions. In breast diseases, CEUS can provide more comprehensive blood flow information, aiding in more accurate diagnosis and assessment of the condition. Through this study, we can further understand the CEUS characteristics of breast lesions, providing more accurate guidance for clinical diagnosis and treatment.

1. The Diagnostic Application Value of Contrast-Enhanced Ultrasound for Breast Tumors

Contrast-Enhanced Ultrasound (CEUS) is a technique that uses the harmonic signals generated by ultrasound contrast agents to increase the contrast between blood cells and surrounding tissues in images. This technology can detect micro-vessels with diameters less than 100 micrometers, allowing for better observation of the number, shape, distribution, and perfusion of micro-vessels inside and around tumors, without being affected by motion artifacts from surrounding organs or other tissues. The specific application values of CEUS in the diagnosis of breast tumors include:

1.1. Clear Display of the Various Layers within the Breast

Ultrasound examination can clearly display the various layers within the breast, including the skin, subcutaneous tissue, glandular tissue, and ductal system. This helps physicians to determine the tumor's location, size, shape, and its relationship with surrounding tissues.

1.2. Identification of the Physical Properties of Tumors

Ultrasound examination can differentiate the physical properties of breast tumors, such as whether they are cystic or solid. This is crucial for determining the nature of the tumor and formulating treatment plans.

1.3. Real-Time Dynamic Observation of Lesion Activity and Elasticity, and Assessment of Blood Flow

Ultrasound examination allows for real-time dynamic observation of the tumor's activity and elasticity, and for assessing the blood flow within the tumor. This information aids physicians in evaluating the malignancy level and prognosis of the tumor.

1.4. The Assurance of Lesion Unfounded by X-ray or Intact One

Ultrasound examination can detect lesions that are not palpable in clinical examinations or visible in X-ray images, assisting in the early detection and treatment of breast tumors.

Evaluating Suspicious Lesions in Dense Breasts and Post-Implantation of Breast Prostheses: For dense breasts or suspicious lesions post-implantation of breast prostheses, ultrasound examination holds high diagnostic value.

1.5. Non-radiativity

Ultrasound examination is non-radiative, making it a safe method for examining breast lesions, particularly for young women, or those who are pregnant or breastfeeding.

In summary, the Ultrasonic Diagnosis of breast tumors offers multiple values, including clearly displaying the various layers within the breast, differentiating the physical properties of tumors, real-time dynamic observation of lesion activity and elasticity, and assessment of blood flow, identifying lesions not detected by physical examination or X-Ray, evaluating suspicious lesions in dense breasts and post-implantation of breast prostheses, and being non-radiative. These capabilities assist physicians in accurately diagnosing breast tumors, formulating appropriate treatment plans, and assessing patient prognosis.

2. Analysis of Ultra-sonographic Image Features in Breast Mass Contrast Imaging

In the study of sonographic imaging features during breast contrast imaging, enhancement intensity is a crucial observation indicator. Based on the degree of enhancement of the lesion compared to normal glandular tissue during the imaging process, the enhancement intensity within the tumor can be classified into three levels: high, equal, or low.

2.1. Intensity Enhancement

Malignant masses mainly exhibit high enhancement, which may be related to the vascular active substances released by malignant tumor cells. These substances induce the rapid and extensive formation of neonatal vessels within the lesion. Therefore, when the contrast agent enters a malignant lesion, due to the presence of neonatal vessels, a large number of micro-bubbles enter the lesion, resulting in high enhancement. In contrast, benign tumors mainly show low or equal enhancement. This is because the growth of benign tumor cells forms a mass with a space-occupying effect, compressing the surrounding normal blood vessels. The blood vessels within the tumor are mostly branches of normal vessels. Compared to the relatively faster-growing malignant tumor cells, the blood vessels within benign tumors are finer and have a more natural course, resulting in equal or low enhancement during contrast imaging.

2.2. Mode Enhancement

In the study of sonographic imaging features during breast contrast imaging, the manner in which the contrast agent enters the lesion is also a key observation point. Based on the way the contrast agent enters the lesion, enhancement patterns can be categorized into centripetal, centrifugal, and diffuse enhancement. Lesions typically exhibit diffuse or centrifugal enhancement, with no significant difference between benign and malignant tumors in terms of enhancement patterns. This might be due to the breast having less blood supply compared to the liver, allowing only the arterial and venous phases to be observed during contrast imaging, without the portal venous phase characteristics. For malignant lesions, due to the abundance and disordered arrangement of blood vessels, the presence of arteriovenous fistulas, or the formation of vascular rings, the contrast agent enters the lesion and enhances rapidly, often exhibiting diffuse enhancement. In contrast, for benign lesions, where there is an increase in normal blood vessels that are evenly distributed, enhancement often occurs simultaneously at the periphery and interior of the lesion.

2.3. Distribution Form of Contrast Agent

In the study of sonographic imaging features during breast contrast imaging, uniform and non-uniform enhancement are important observational indicators. Benign lesions often exhibit relatively uniform enhancement, which may be due to the consistent diameter and natural course of blood vessels within benign tumors, forming a branching pattern. When the contrast agent enters, it is distributed more evenly, and the venous and lymphatic return systems are normal, making it less likely to have retention and uneven distribution of the contrast agent. In contrast, malignant lesions primarily display non-uniform enhancement. The pathological basis for this might be the cluster-like accumulation of malignant tumor cells, distributed unevenly in the fibrous connective tissue. neonatal vessels within the tumor lack a muscular layer and are thin with high permeability. Their rapid and extensive formation can easily lead to arteriovenous fistulas and disordered vascular formations. Post-contrast, malignant tumors exhibit twisted and disordered vascular clusters within the mass. Some areas, due to a higher content of fibrous elements or connective tissue, show relative hypo-perfusion post-contrast, leading to noticeably uneven distribution of the contrast agent within malignant tumors.

2.4. Post-Border Enhancement

In the study of sonographic imaging features during breast contrast imaging, the clarity of the tumor border after enhancement is also one of the important observational indicators. Benign tumors, primarily fibroadenomas, often have a capsule surrounding them, resulting in a clear boundary with surrounding tissues after contrast enhancement. Most benign lesions have clear borders post-enhancement, but a small portion of benign lesions may have unclear borders after enhancement. Malignant tumors have the characteristic of invading surrounding areas. Cancer cells can infiltrate and grow into surrounding glandular tissues or interstitium, destroying nearby fibrous tissues, blood vessels, lymphatic vessels, nerves, and even invading muscles and fat tissues. Post-contrast, small infiltrative foci around the tumor, which cannot be displayed in two dimensions, may be observed. The periphery of the tumor may appear spiky or crab claw-like, extending into the surrounding glandular tissues.

2.5. Peripheral Penetrating or Distorted Vessels

When malignant tumors display peripheral penetrating or radial enhancing signs, the accuracy of diagnosing them as malignant is indeed higher. This is because the neonatal vessels within the malignant tumor continuously extend outward, causing the blood vessels to become twisted and disorganized. These neonatal vessels, in conjunction with the surrounding fibrous tissues, create penetrating vessels around the tumor, which appear radial when there are many such vessels. These features differ from those of benign tumors. Benign tumors usually have clear boundaries and normal surrounding tissue structures, exhibiting uniform enhancement after contrast. Malignant tumors, on the other hand, show non-uniform enhancement, unclear boundaries, and are accompanied by penetrating or radial vascular enhancement signs. Therefore, when peripheral penetrating or radial enhancing signs of malignant tumors are detected in contrast-enhanced ultrasound examinations, in conjunction with other radiological characteristics and clinical manifestations, a more accurate diagnosis of a malignant tumor can be made. This has significant implications for guiding clinical treatment and assessing prognosis.

2.6. Perfusion Damage Within the Lesion

The appearance of perfusion defects within lesions following breast tumor contrast imaging indeed strongly indicates the possibility of breast cancer. When the percentage of perfusion defects is significantly higher in malignant masses compared to benign ones, this sign alone has a high specificity for diagnosing the nature of breast lesions as benign or malignant. The pathological basis for perfusion defects primarily lies in the cancer cells proliferating faster than the formation of new blood vessels. When the tumor grows rapidly and becomes large in size, it leads to relative ischemia and hypoxia internally, resulting in necrosis and liquefaction. This causes areas where the contrast agent cannot enter, leading to perfusion defects. Therefore, when contrast-enhanced ultrasound reveals perfusion defect areas within a breast tumor lesion, a high suspicion for malignancy should be considered. Combined with other imaging features and clinical manifestations, the nature of the breast tumor can be diagnosed more accurately. It is important to note that while the sign of perfusion defects has certain specificity in diagnosing breast cancer, not all malignant masses will exhibit this characteristic.

In summary, the contrast-enhanced ultrasound characteristics of malignant breast lesions primarily include non-uniform high enhancement, unclear boundaries of the tumor post-enhancement, peripheral vessels penetrating the tumor or radial enhancement, and perfusion defect areas within the lesion. In contrast, the characteristics of benign breast lesions in contrast-enhanced ultrasound are primarily uniform low or equal enhancement, with clear tumor boundaries post-enhancement. These features are helpful in differentiating between benign and malignant breast lesions. Contrast-enhanced ultrasound examination can provide qualitative analysis of the nature of breast masses, as well as richer information through quantitative analysis. The sensitivity, specificity, and accuracy of diagnosing breast masses have certain application value in the diagnosis of breast diseases.

Conclusion

The growth pattern of malignant tumors is often infiltrative, meaning that cancer cells are likely to seep into surrounding tissues, disrupting normal tissue structures. Newly formed micro-vessels play a crucial role in malignant tumors, invading the periphery to provide nutrients and oxygen to cancer cells. Contrast enhancement improves the visibility of micro-vessels, as contrast agents enhance the contrast of blood vessels, making them more clearly visible in ultrasound images. Through contrast enhancement, we can more clearly observe the distribution and morphology of blood vessels inside and around malignant tumors. The ultrasound images post-contrast enhancement can more accurately reflect the actual size and shape of the tumor, thus aligning more closely with pathological findings. Therefore, by employing ultrasonic imaging enhancement techniques, we can diagnose malignant tumors in a more accurate manner and provide more reliable information for the treatment and prognosis assessment of this disease.

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