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Advances in the Diagnosis of Breast Tumor by Using Imaging Technology

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Abstract

Breast tumor is the most common tumor in the world. The most important method to reduce the mortality due to breast tumor is diagnosed and found as early as possible. Imaging technology is one of the most important means to help doctors diagnose tumor early. This paper first simply introduces the common imaging technology. Then the mechanism and application of the ultrasonic elastic imaging technology in the diagnosis of breast tumor are summarized and discussed detailly. The methods for image treatment are introduced also. At last the development trend is analyzed. It is shown that the ultrasonic imaging technology is the most convenient and the cheapest relative to other imaging technologies such as nuclear magnetic imaging (NMI) and computer tomography (CT). Especially the ultrasonic elastic imaging technology can provide not only imaging information but also mechanism parameters, which helps to improve the accuracy of diagnosis obviously. Therefore, the ultrasonic elastic imaging technology is worthy of being studied further. More effective image analysis method is required.

Keywords

Breast Tumor, Ultrasonic Elastic Imaging, The Method for Image Treatment

1. Introduction

Breast tumor is the most common tumor in the world. The most important method to reduce the mortality due to breast tumor is diagnosed and found accurately as early as possible [1]. However, the period of diagnosis is often late. Therefore, it is required to promote the ratio of early diagnosis. How to find and diagnose early is the key problem. Imaging technology is one of the most important means to help doctors diagnose tumor fast. Up to now, many imaging technologies have been developed such as X-ray, NMI, CT, ultrasonic imaging, etc. The resolution of image, accuracy of diagnosis and speed of image analysis are improved greatly. The ultrasonic elastic imaging developed in recent years promotes greatly the quantitative diagnosis of tumor. Surely, the apparatus for tumor imaging, basic theories and analysis methods for images are required studied further to improve the accuracy of diagnosis.

This paper summarized the development of imaging technology in the diagnosis of breast tumor. The ultrasonic elastic imaging technology is mainly discussed. The advantages are introduced. The disadvantages required to be studied further are also analyzed.

2. Common Detection Methods by Using Imaging Technology

It is the important means to detect breast tumor by using imaging technology. Up to now, a series of methods have been developed, such as infrared breast scanning, mammography with molybdenum target, breast NMI (nuclear magnetic imaging), Breast-duct endoscope, conventional ultrasonic detection, Ultrasonic guided breast mass biopsy, etc.

1) Detection method by infrared breast scanning: The absorptive capacities of infrared light by different tissues are different. Clinician can judge the hyperplasia of mammary glands, cyst, benign and malignant lesions, etc. by observing the image of breast tissue formed by infrared irradiation [2].

2) Detection method by mammography with molybdenum target: This method is widely used in the diagnosis of breast tumor at present. The absorptive capacities and attenuation of X-ray varied with tissues. The normal and unnormal tissues will form obvious contrasting image after X-ray irradiation. The method of mammography with molybdenum target has unique advantages for the examination of slight calcification in breast [3] and the detection sensitivity of breast tumor is 80% - 89% [4]. However, if the breast is small and meanwhile the glandular tissue is dense, the missed diagnosis ratio will rise [5]. For example, the malignant tumor near the chest wall or at the edge of the gland is not easy to be detected. Meanwhile, X-ray is harmful to the patients, so the detection method of mammography with molybdenum target is not suitable for the patients in pregnant, lactation and young women.

3) Detection method by NMI: NMI is sensitive to the materials containing hydrogen atoms. The imaging by NMI is not affected by the density of the breast tissue and can perfectly show the edge shape of the breast lesions and the invasion scope. The clinical application of NMI gradually popularizes. Enhanced NMI can distinguish lesions and benign tissues better and improve the accuracy of diagnosis. NMI has high correct ratio for small lesions, multicentric lesions and multifocal breast tumors, which is convenient for preoperative staging and the design of surgical plan. Compared with the method of by mammography with molybdenum target, NMI can diagnose breast disease in wider scope and meanwhile has not radiation. However, NMI can still report false positive, the

cost is high, and there is the risk of allergy of contrast agent during using NMI. These factors restrict the application of NMI in the diagnosis of breast tumors [6] [7].

4) Detection method of dedicated breast PET (DBPET), DBPET is a kind of parameters for imaging diagnosis by using multiple PET tracer. It can improve the sensitivity of detection and the resolution obviously. The experimental results show that the sensitivity can be 91% [8], positive predictive value can be as high as 95% and the accuracy of diagnosis is 92%. However, the cost is high and only a few hospitals have DBPET.

5) Detection method by using breast-duct endoscope: The doctor can determine the diseased duct of patients with nipple discharge and improve the diagnosis accuracy of protuberant lesion in duct, and position the lesion by this method. It is suitable for the detection of tumors with small diameter (1 - 2 mm), which is convenient for the minimally invasive treatment of breast tumor.

6) Detection method by using conventional ultrasound: The propagation speed and attenuation of the acoustic wave are different in different tissues. So the property of tissues can be distinguished by the ultrasonic imaging according to the data of reflection and attenuation of acoustic wave. Ultrasonic detection has many advantages such as convenient, cheap, no radiation, sensitive, high repeatability, dynamic imaging, etc. So it is one of the most widely applied method in the examination of breast tumors. There is conventional two-dimensional gray scale ultrasonic imaging, three-dimensional ultrasonic imaging and contrast-enhanced ultrasonography, etc. besides conventional ultrasonic imaging. a) Two-dimensional gray scale ultrasonic imaging can show the structure of each layer from shallow to deep. Common two-dimensional ultrasonic images of breast tumor have the following characteristics: i) The shape of the lump is irregular and in serrate, prickly or crablike. The lump shrinks with pressure. ii) The internal echo in lump is not uniform and mainly hypoechoic. There is area without echo if the tissue is liquefying necrosis. iii) The echo decays at the back of the lump, which is caused by the hyperplasia of the internal connective tissue. iv) The anteroposterior diameter of the malignant tumor is larger than the transverse diameter. v) The halo ring can be observed around the lump which is formed by the wide and nonuniform strong echo. vi) The lymph node has metastasized locally when most of the patients go to see a doctor. The lymph node metastasis can be found at the supraclavicular fossa in the late period. vii) Because the blood supply is rich, multiple arterial blood flow, neovascularization and arteriovenous fistula can be observed inside the lump. b) Three-dimensional ultrasonic imaging makes up for the shortages of two-dimensional ultrasonic imaging. It can show and divide the image of lesions all around from horizontal, longitudinal and coronal sections. The stereoscopic shape and spatial relationship can be better displayed than by two-dimensional ultrasonic imaging, so the scale of the lump can be measured precisely [9]. c) Contrast-enhanced ultrasonography combines the two-dimensional ultrasonic imaging and new type of

acoustic contrast agent. Accordingly, the gray scale perfusion image of the lesion tissues can be shown in real time [10]. However, the operation is difficult because the effects of the ultrasonic enhancement require the subjective visual inspection of doctors during operation, and meanwhile the property of the imaging is affected by many factors such as the concentration of the contract agent, dose, injection speed, etc. It is needed to study the means on how to control the operation and reduce the miscarriage of justice. d) Ultrasonic-guided biopsy of breast masses has the advantages of convenience, safety and little trauma. The lump of breast can be punctured conveniently under the guidance of ultrasonic and the diagnosis results can be obtained fast. The ratio of false negative by this method is only 3.6% [11].

7) Ultrasonic elastic imaging technology: It is a new method to detect the breast diseases in recent years which is formed by combination of the ultrasonic and mechanics measurement. The elastic modulus or stiffness is varied with the tissues. Even for the same tissue at different pathological state, the elastic modulus is different [12]. Based on these characteristics, the image of tissues and the distribution of elastic parameters can be obtained by measuring the ultrasonic information of the tissues under deformation. Then the normal and abnormal tissues can be distinguished. The increase of the hypertrophic connective tissues and collagen outside the breast cancer leads the rise of the stiffness of tumor. The acoustic speed becomes high. On the contrary, the benign tumor such as the tissue of the fibroadenoma is soft and the acoustic speed is small [13]. The tendentious diagnosis can be made according to the mechanical information.

Supersonic elastic imaging technology adopts the quasi static excitation with low frequency to cause the deformation of focus. Then the acoustic data are collected and treated to obtain the elastic coefficients of the interested region. The pathological nature can be quantized accordingly [14].

3. Supersonic Wave Elastic Imaging Technology

The mechanism of supersonic elastic imaging technology is as follows: A series of acoustic radiation pulses are emitted by linear array probes and propagates in the direction vertical to the probe axis. The pulses are continuous focused at different depth of the target tissues to cause the variation of the deformation, speed and their distribution [15]. Some ultrasonic probes are used to collect the acoustic information. Based on the data, the shear wave speed and elastic modulus of the tissues can be computed. Supersonic elastic imaging technology can be divided into three types by the excitation ways to cause the deformation of tissues: 1) static strain imaging; 2) elastic imaging of tissues in real time; 3) ultrasonic elastic imaging by acoustic radiation force, including acoustic radiation force imaging and shear wave elastography (SWE). During applying static strain imaging and elastic imaging of tissues in real time, pressure is acted directly on the surface of the tissues. The excitation force is outside the tissues. Ultrasonic elastic imaging by acoustic radiation force makes the deform inside tissues and the excitation force is inside the tissues. The technology of ultrasonic elastic imaging in real time is evaluated the elastic coefficients by the deformation of tissues. The deformation varies with tissues and forces, but the elastic is the same for the same tissues even the force is different [16]. At present, the diagnosis by the technology of ultrasonic elastic imaging can be divided into three kinds: 1) Scoring method: to diagnose by scoring according to the colors of the elastic images. 2) Strain ratio method: to measure the strains of the normal tissues and the pathological tissues first and then diagnose by the ratio of these two strains. 3) Strain histogram method: to analyze the texture changes of the tissues' strain. Scoring method and strain ratio method are mainly used in local space occupying lesions such as breast and thyroid. Strain histogram method mainly used in the diffuse lesions [17]. Conventional ultrasonic determined the acoustic resistant of the tissues and display by gray scale, while ultrasonic elastic imaging shows the elasticity of tissues and can be displayed in color image or data [18]. Because the difference of the elastic modulus between the benign lesion and malignant lesion is large (**Table 1**), the color image is easy to be divided and the tumor can be easily distinguished [19]. By this way, the relative value of elastic parameters at each position of breast can be clearly shown. If there is a tumor, not only it can be correctly diagnosed, but also the types of tumor can be differentiated (**Figure 1**). Besides the ultrasonic elastic image, the receive operating characteristic curve (ROC) is also used to help the diagnosis of breast tumor. **Figure 2** shows the ROC of the maximum elastic modulus, average elastic modulus [20] [21]. This figure can further help the doctor to judge the accuracy and

Table 1. Comparison between benign lesion and malignant lesion.

Group	Maximum elastic modulus	Minimum elastic modulus	Average elastic modulus
Benign lesion (n = 76)	65.30 ± 15.34	22.91 ± 8.14	47.43 ± 14.52
Malignant lesion (n = 63)	157.10 ± 24.58	24.32 ± 6.94	78.09 ± 20.53
t	26.867	1.085	9.964
P	<0.001	0.28	<0.001

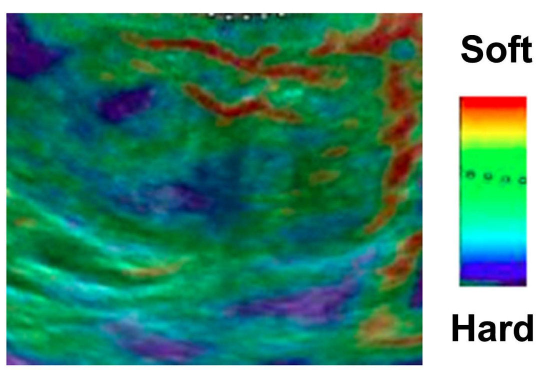

Figure 1. A ultrasonic elastic image (Blue means small elastic value and red means high elastic value).

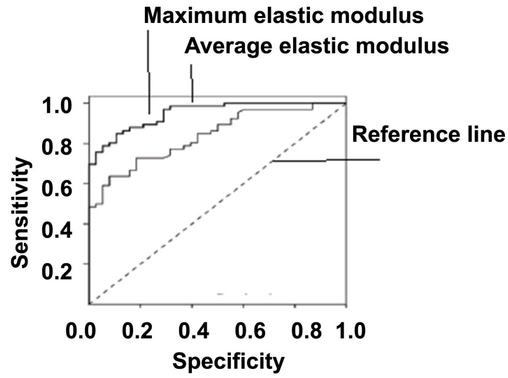

Figure 2. ROC curve of three ultrasonic elastic image (maximum modulus and average elastic modulus).

authenticity of diagnosis. If SWE combines with other technologies, the accuracy of diagnose will be better than that used by one method [22].

4. Method for Image Analysis

Accurate image analysis can help doctors to recognize and position the lesions correctly. Recognition of medical image is related with mathematical modeling, digital image treatment, pattern recognition and machine learning. It contains classification of medical image, positioning and segmentation of the pathological region in images, registration and fusion of medical image, retrieval of medical image based on contents, three-dimensional reconstruction and visualization of medical images. The following factors should be mainly considered [23] in image analysis:

1) Shape: the common characteristics of medical images are aspect ratio and edge smoothness. The aspect ratio is one of the most important indexes in the classification of benign or malignant tumors. Malignant tumors often grow in longitudinal direction and the aspect ratio are larger than 1.0 because of the invasive property and predacity to nutrition while benign tumors are on the contrary. The edge smoothness reflects the relation between the focus and the surround tissues. Most of the malignant tumors have no capsule or the capsule is not complete. The edge of the focus is fuzzy and unsmooth with the surrounding tissues. The benign focus often has complete capsule and smooth edge. 2) Texture is one of the common features of imaging. It reflects the characteristics of arrangement in regular change. Repeated, locally consistent and random appeared gray distribution can be used to distinguish the contents of images. This character has good anti-noise capability and so is used widely. However, it can only capture local but not global characters.

Recently, machine learning methods have been used more and more in image analysis with the development of hardware and artificial intelligence. This kind of methods can capture the feature information in pathological images manually first. Then let computers learn the information. The computer can judge the properties of breast tumors after learning automatically. Early method used in image analysis is BP artificial network. Before learning and recognition, the image must be analyzed to obtain the edge characteristics such as circularity, area ratio, aspect ratio, etc.

With the development of deep learning algorithm, convolutional neural network achieves great success in image recognition and segmentation. Researchers apply the convolutional neural network gradually in the breast tumor. This method can automatically learn the characteristics from the pathological images obtained by ultrasound or CT or NMI. So the process of manual extraction can be omitted and the man-made factors can be removed. Many models based on CNN have been built for the recognition and segmentation of breast tumors [24] [25].

5. Conclusions

Breast tumor is the most common tumor in the world. Study and practice on the detection of breast tumor have been carried out for many years. Many detection methods have been built. Imaging technology is one of the most important means to help doctors to diagnose tumors. The ultrasonic elastic imaging technology is one of the most promising methods in the diagnosis of breast tumor which attracts many researchers to study and apply.

The ultrasonic elastic imaging technology not only makes up for the defects of conventional imaging technology which cannot detect the stiffness, but also can provide the information of the focus' shape. At present, the detection can only be processed by the comparing between the normal and abnormal tissues. In the future, the mechanical properties of different tissues should be tested. The responses of different tissues under ultrasonic and force should be studied in detail. These studies can increase the accuracy and the application scope of the ultrasonic elastic imaging technology.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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