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Application of ultrasound diagnosis in cardiac and liver diseases

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Abstract. Ultrasonography is a non-invasive imaging modality widely used to evaluate and diagnose many diseases. The purpose of this article is to provide a more detailed overview of the use of ultrasound in the diagnosis of heart and liver disease. In addition to a basic introduction to heart and liver disease, this article will explore specific applications of ultrasound in specific heart and liver diseases. In terms of heart disease, ultrasound plays an important role in the diagnosis of coronary atherosclerotic heart disease, valvular heart disease and congenital heart disease. Ultrasound can assess the degree of narrowing and blood flow in coronary arteries to help determine a patient's cardiovascular risk. For valvular heart disease, ultrasound can detect and evaluate the function and abnormality of the heart valves, providing information about valve stenosis or regurgitation. For congenital heart disease, ultrasound can reveal structural abnormalities and hemodynamic changes in the heart, helping to determine the type and severity of the lesion. In liver disease, ultrasound plays an important role in the evaluation of pathologies such as cirrhosis and hepatocellular carcinoma. Ultrasound can assess the shape, size, and texture of the liver, help detect and diagnose cirrhosis, and assess liver function and disease progression. In addition, ultrasound is also of great significance for the early diagnosis and monitoring of hepatocellular carcinoma, which can reveal the location, size and blood flow of the tumor. The role of ultrasound in diagnosing and monitoring disease will expand further with advances in technologies such as artificial intelligence and elastography. In conclusion, ultrasound plays a key role in the assessment, diagnosis and monitoring of heart and liver diseases and has many advantages. With the further development of technology and the expansion of application, the position of ultrasound in clinical practice will be further strengthened.

Keywords: ultrasonography, cardiac diseases, liver diseases.

1. Introduction

Medical ultrasound imaging mainly utilizes the principle that ultrasonic waves travel at different speeds in different human tissues to obtain image information. Ultrasonic waves used in clinical diagnosis are generally generated by the piezoelectric effect generated by piezoelectric elements. In addition, applying the Doppler effect in diagnosis can infer the presence or absence of blood flow or tissue activity. The Doppler effect is also the theoretical basis of color Doppler ultrasound imaging. Ultrasound can be divided into A-mode ultrasound, B-mode ultrasound, 3D ultrasound and Doppler ultrasound according to different imaging principles and inspection dimensions. Different types of ultrasonography can be used in the diagnosis of different organs and different diseases. Ultrasonography is a non-invasive

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imaging technique with multiple advantages, including no radiation, low price, and portability. But ultrasound presentation depends on the operator's skill [1].

Ultrasound imaging is widely used in the diagnosis of heart and liver diseases. Cardiac disease includes coronary atherosclerosis, heart valve disease, congenital heart disease, etc. Severe heart disease can cause death, so timely diagnosis and treatment play an important role. The intuitive detection of the heart by echocardiography greatly shortens the time required for disease diagnosis, which also greatly improves the survival rate of patients. In addition to heart disease, ultrasonography is widely used to examine the liver, a solid organ. Ultrasound imaging can directly assess the degree of cirrhosis and blood flow in the liver. For liver tumors, ultrasound can directly measure tumor size and blood flow within the liver cancer. With the development of interventional therapy technology, ultrasound can be used as a guiding tool for puncture and aspiration operations such as liver cysts and ovarian cysts [1]. This article mainly discusses the application of ultrasonography in diagnosing cardiac and liver diseases. This article will also highlight the advantages and limitations of ultrasound in these clinical settings.

2. Application of ultrasound in cardiac disease

2.1. Coronary Atherosclerotic Heart Disease

Coronary atherosclerosis is a disease in which atherosclerotic plaques form inside the coronary arteries. Coronary heart disease is the most common type of organ lesion caused by atherosclerosis and is one of the diseases that seriously endanger human health [2]. Intravascular Ultrasound Imaging (IVUS) uses minimally invasive catheter technology to provide ultrasound visualization of blood vessel ratios. Intravascular ultrasonography can not only display the stenosis of coronary arteries and the extent, shape and degree of atheromatous plaques, but also accurately calculate the stenosis rate of the lumen. It also assesses the nature of atheromatous plaques and identifies vulnerable plates [3]. It can help doctors more accurately determine the severity of lesions and guide the formulation of treatment plans.

Coronary atherosclerosis also has a certain impact on myocardial movement. TDI technology has significantly improved the sensitivity and accuracy of echocardiography in detecting myocardial systolic and diastolic function. Abnormal wall motion can be analyzed by tissue Doppler imaging. Tissue Doppler imaging (TDI) can extract the Doppler frequency shift signal generated by myocardial motion for analysis, processing, and color coding, and perform qualitative and quantitative analysis of myocardial motion [4]. TDI technology significantly improves the sensitivity and accuracy of echocardiographic detection of reginal wall motion abnormality [1]. TDI can assess the heart's diastolic and systolic function by quantifying the mitral valve's annual relaxation velocity and myocardial strain and strain rate [5, 6]. The quantification of myocardial strain and strain rate by TDI can capture the abnormal changes of myocardial function in the early stage before the cardiac function shows obvious abnormality to understand the mechanical function state of the heart more comprehensively [7]. Speckle Tracking Technology (STI) is similar in function to TDI. But overcomes the disadvantage of TDI technology's angle dependence. STI technology uses texture analysis and spot automatic tracking technology to track frame by frame the information of scattering spots generated by small structures in the region of interest in the cardiac cycle, and directly measure myocardial velocity, displacement, strain and strain rate, etc [1]. Both of these approaches could improve the diagnostic accuracy of coronary artery-related diseases [8].

2.2. Cardiac Valve Disease

Mitral stenosis, the most common rheumatic heart valve disease, causes enlargement of the left atrium [9]. In M-mode ultrasound, the opening amplitude of the anterior and posterior lobes decreases, the posterior and anterior lobes move in the same direction, and the EF slope slows down. The depression at point F between the two peaks of E and A in the anterior lobe disappeared, and its activity curve showed a platform shape, a "Wall-like" change (Figure 1). The two-dimensional ultrasound left ventricular long-axis view showed that the mitral valve leaflets were thickened, the echo was enhanced, the valve orifice was narrowed, and the anterior leaflet of the mitral valve could present a "dome-like"

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change. In the short-axis view of the mitral valve, a "fish-like" change was seen (Figure 1). On color Doppler imaging, it appears as colorful jet streams with fast blood flow [1]. 3D echocardiography can dynamically display the three-dimensional anatomical structure of the mitral valve in real time, which is more advantageous than two-dimensional ultrasound [10]. Echocardiography has important diagnostic value for mitral valve stenosis, with a diagnostic accuracy of 100% [11].

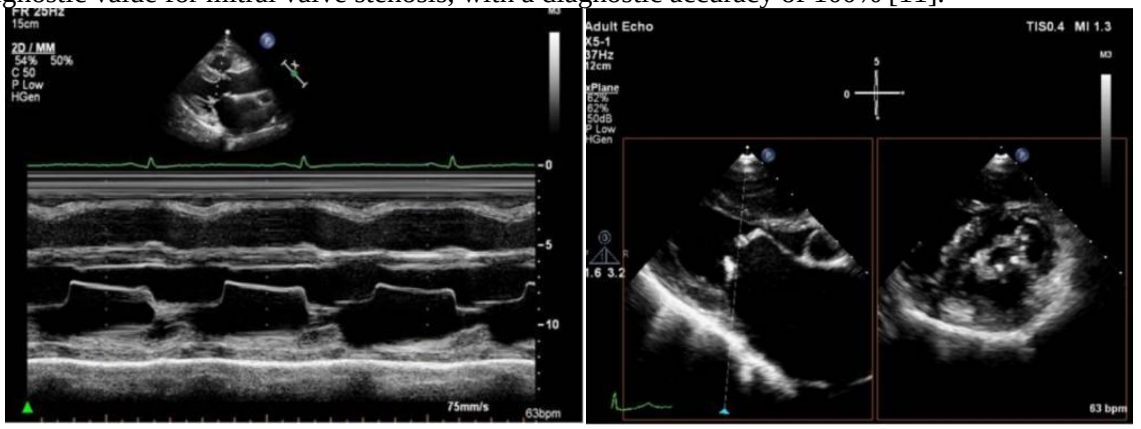

Figure 1. Left is "Wall-like" changes in mitral valve stenosis, midle is “fish-like” change, right is “dome-like” change [1].

Aortic valve stenosis is common in degenerative aortic valve diseases, such as calcification and fibrosis [12]. Concentric hypertrophy of the left ventricular wall can be seen on echocardiography, and the thickness is generally greater than 12mm. Aortic valve thickening, echo enhancement, orifice spacing decreased. Color Doppler showed a high-velocity jet signal in the systolic phase of the aortic valve (Figure 2). Continuous Doppler showed a single-peak shape, the velocity of the ascending branch slowed down, the peak shifted back, and the ejection time was prolonged. Three-dimensional echocardiography can fully demonstrate the overall shape of the aortic valve. Three-dimensional ultrasound can intuitively make a qualitative diagnosis of aortic stenosis and perform a more accurate quantitative evaluation of the stenotic valve [1]. Echocardiography is the preferred method for noninvasive evaluation of aortic valve stenosis [13]. It can display the shape and range of motion of the stenotic valve, clarify the degree of stenosis, and provide etiological diagnosis information [1].

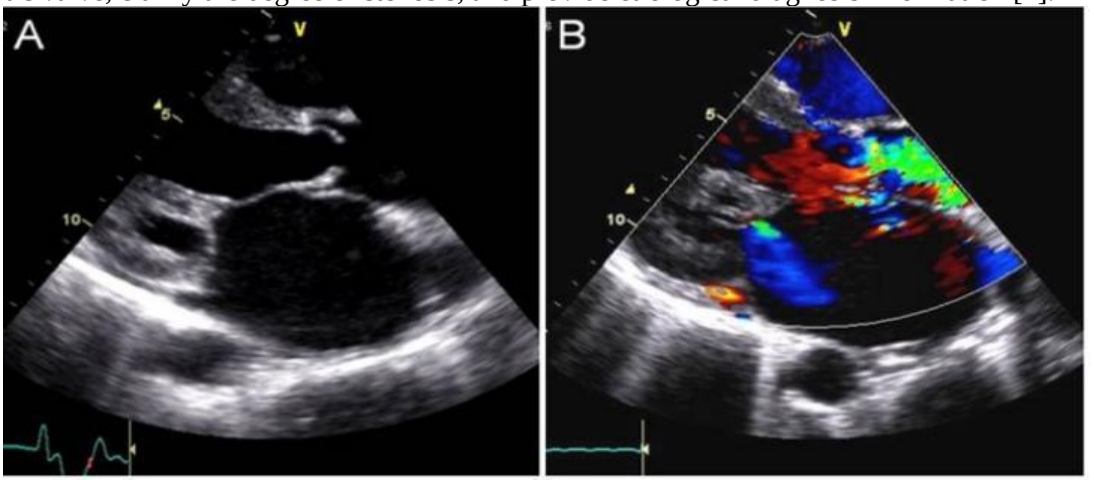

Figure 2. Ultrasonographic manifestations of aortic stenosis in rheumatic heart disease [1] A: Two-dimensional ultrasonography shows restricted opening of the aortic valve. B: Color Doppler shows the high-velocity firing signal of the aortic ostium.

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2.3. Congenital heart disease (CHD)

Congenital heart disease refers to congenital vascular malformations that already exist at birth [14], including atrial septal defect, Patent ductus arteriosus, etc.

Atrial septal defect (ASD) is one of the most common congenital heart diseases [15]. In the M-mode ultrasonography, the interventricular septum and the posterior wall of the left ventricle show the same movement. Among them, right ventricular enlargement on the left ventricular long axis view is the most important indirect sign of atrial septal defect. Discontinuity of echogenic continuity in the upper middle part of the atrial septum in the four-chamber view on 2D ultrasound. In the color Doppler ultrasound, the blood flow is at the defect, and the left-to-right shunt presents a red-dominated shunt signal. Transesophageal echocardiography (TEE) is an option when transthoracic ultrasound images are unclear [1]. TEE clearly shows the relationship between the stump of atrial septal defect and the superior and inferior vena cava and coronary sinus. 3D TEE can also dynamically display stereoscopic images of the defect site and adjacent structures in real time. The operator can observe the shape, size and area of the room defect from any section or angle of view. This helps to guide the rational formulation of atrial septal defect treatment plan [16].

Patent ductus arteriosus (PDA) is one of the most common congenital heart diseases [17]. The ductus arteriosus is an important normal physiological channel between the fetal pulmonary artery and the aorta. Failure to close the ductus arteriosus results in left heart enlargement and early pulmonary hypertension. The catheter's shape, inner diameter, and length can be visualized on a 2D echocardiogram. Color Doppler ultrasonography showed abnormal shunt bundles between the descending aorta and pulmonary artery, which is also an important basis for diagnosing PDA. Spectral Doppler shows continuity across the cardiac cycle or left-to-right shunt spectrum across diastole at the distal pulmonary artery or the ostium of the ductus arteriosus. Left-to-right shunts can occur in severe pulmonary hypertension. Color Doppler echocardiography has a high diagnostic accuracy in the diagnosis of PDA [1].

3. Application of ultrasound in liver disease

3.1. Cirrhosis

Cirrhosis is chronic damage to the liver from one or more causes, with portal hypertension and liver dysfunction later in the disease [18]. Ultrasonography is widely and cost-effectively used to diagnose and evaluate liver cirrhosis. Ultrasound imaging is mainly used to estimate the degree of liver cirrhosis by quantitative assessment of liver fibrosis with TE technique [19]. TE technology is based on the principle of ultrasound elastography. An ultrasound probe produces low-frequency pulse waves that travel through the liver and cause slight vibrations in liver tissue. The probe can also record the speed of sound waves. Since fibrosis can increase the stiffness of the liver tissue and thus affect the pulse wave's propagation speed, the greater the stiffness of the liver, the faster the pulse wave propagation speed. According to the sound wave's propagation speed, the liver's stiffness can be calculated. This parameter is called the liver elastic modulus (LSM). The higher the LSM value, the harder the liver tissue. In the meta-analysis by Chon et al., it was pointed out that the sensitivity and specificity of this technique can be as high as more than 80% [20]. Therefore, TE technology has greatly contributed to the quantitative diagnosis of liver cirrhosis. However, the technique also has limitations. For overweight or obese patients, the accuracy of the results may be affected due to the interference of fat tissue with the ultrasound transmission. TE technology also cannot provide detailed anatomical information inside the liver, it is only a tool to assess the degree of fibrosis [21]. TE technology is mainly used in one-dimensional ultrasound. Portal vein diameter, liver size, and intrahepatic nodules can be measured on 2D abdominal ultrasonography. Portal vein dilatation can be shown on color Doppler ultrasonography, and thrombus can form in individual portal veins. In pulsed Doppler, the velocity of portal vein blood flow is reduced, and some of them show bi-directional or even reversed blood flow away from the liver [1].

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3.2. Hepatocellular carcinoma

Hepatocellular carcinoma (HCC) is a common primary liver cancer and a malignant tumor [22]. Early diagnosis of HCC is very important because the number of deaths from this tumor is increasing year by year. Ultrasonography can be applied to monitoring HCC patients, aiming to identify HCC in its early stages [23, 24]. Ultrasonography can be applied to monitoring HCC patients, to identify HCC in its early stages. In two-dimensional ultrasonography, liver cancer nodules are mostly round or quasi-round; the internal echo of nodules is more complex and hypoechoic is more common. The internal echo of cancerous nodules is uneven, and some liver cancers have surrounding dark rings, which have high diagnostic specificity, as shown in the figure 3. Mild echogenicity can also be seen posterior to the nodule. On color Doppler ultrasonography, linear colored blood flow can sometimes be seen inside liver cancer. The sensitivity of contrast-enhanced ultrasonography (CEUS) in the diagnosis of HCC is as high as 96% [25], which can be manifested as "fast in and fast out", that is, after the injection of contrast agent, the overall uniformity of the lesion in the early arterial stage is enhanced, which is earlier and stronger than that of the surrounding liver parenchyma. Subsequently, the echo of the lesion faded, and the lesion showed hypoechoic changes in the portal venous and delayed phases. CEUS can also be used as a follow-up imaging modality for indeterminate nodules on CT or MRI before biopsy [26]. Overall, ultrasound has become a routine screening and monitoring method for HCC. Doppler ultrasound can well detect blood vessels in and around the tumor. CEUS also significantly affects the diagnosis of HCC [27].

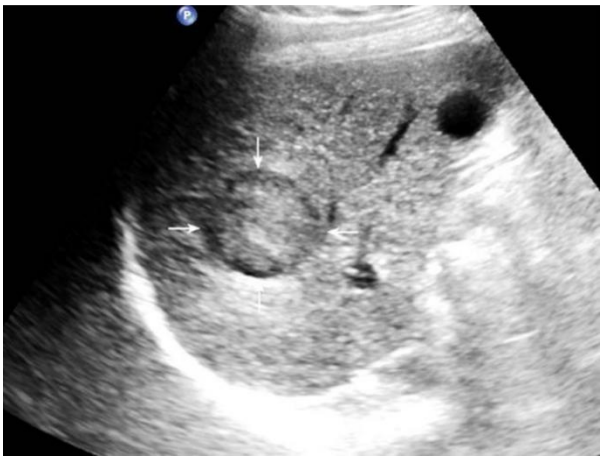

Figure 3. Gray-scale ultrasound, primary hepatocellular carcinoma, hypoechoic heterogeneous mass in the right liver lobe, with clear boundaries and dark rings (indicated by the arrow) [1].

4. Conclusion

Ultrasound imaging is widely used and very important in clinical practice. It plays a vital role in heart and liver tests and disease monitoring. In addition to conventional two-dimensional ultrasonography, the application of techniques such as three-dimensional ultrasonography, elastography, and contrast-enhanced ultrasonography can further improve the diagnostic accuracy and clinical utility of ultrasonography in these fields. Ultrasonography has many advantages, such as non-invasiveness, no radiation, real-time imaging, etc. It can be performed quickly on the spot, providing dynamic information to doctors, and combining with other imaging techniques and laboratory results to assist clinical decision-making. However, the results of ultrasonography are often highly dependent on the experience and technical level of the operator, which may lead to inaccurate disease diagnosis and uncertainty in the lesion detection rate.

In the future development of the medical field, institutions related to ultrasound medicine can develop artificial intelligence (AI)-assisted diagnosis. AI can use deep learning and image analysis technology to help analyze and interpret ultrasound images, assist doctors in diagnosis and decision-making, thereby improving the accuracy of disease diagnosis and early detection rate. In addition, for the lack of medical

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resources in remote areas, remote ultrasound not only improves the portability of ultrasound equipment, but also enables doctors to perform ultrasound examinations on patients in remote areas. This remote ultrasound technology combined with the Internet and remote communication can realize real-time communication and remote guidance between doctors and patients, and improve the accessibility and efficiency of medical services.

Overall, innovation and continuous research in ultrasound technology continues to drive its application and development in the medical field. With the continuous development of technologies such as artificial intelligence-assisted diagnosis and remote ultrasound, ultrasound examination will be more accurate and reliable, and can meet the needs of more patients.

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