Study on the Application of Cardiac Ultrasound in the Diagnosis and Evaluation of Cardiac Function in Patients with Chronic Heart Failure

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Abstract: The objective of this study was to examine the potential of cardiac ultrasound in the diagnosis and evaluation of cardiac function in patients with chronic heart failure. This study aimed to address the high morbidity and mortality associated with chronic heart failure. In terms of research methods, the latest progress in cardiac ultrasound technology and its application in the diagnosis of chronic heart failure was reviewed. The role of cardiac ultrasound in the evaluation of cardiac structure (such as ventricular size and wall thickness), valvular disease detection and cardiac function (such as ejection fraction measurement) was analyzed. Important results indicate that echocardiography, a non-invasive, dynamic detection method, can accurately assess cardiac structure and function in patients with chronic heart failure, providing comprehensive information for diagnosis and reference for optimization of treatment options. Cardiac ultrasound has significant application value in the diagnosis and cardiac function evaluation of patients with chronic heart failure, which is beneficial for improving diagnostic accuracy and prognosis.

Keywords: Chronic Heart Failure; Diagnosis; Cardiac Function; Cardiac Ultrasound; Application Value

1. Introduction

Chronic heart failure is a complex condition that is becoming increasingly prevalent with the aging of the population. According to statistics, the prevalence of chronic heart failure increases with age, making it a significant cardiovascular disease affecting human health. The mortality rate of chronic heart failure in the elderly is also relatively high, which poses a serious threat to the life safety of patients. Jiang et al. [1] demonstrated that the pathogenesis of chronic heart failure is a complex process, with clinical manifestations varying between patients. Common symptoms include dyspnea, fatigue, and edema, which not only affect the daily lives of patients but can also lead to serious complications and even organ failure. Therefore, it is crucial to accurately diagnose and treat chronic heart failure conditions.

Cardiac ultrasound technology employs the propagation of high-frequency sound waves in human tissues to display the structure, function, and hemodynamic characteristics of the heart. With the continuous improvement of science and technology, cardiac ultrasound technology has become increasingly sophisticated, particularly in terms of resolution and accuracy. These advancements have significantly enhanced the diagnostic accuracy of chronic heart failure. Jiang et al. [2] demonstrated that cardiac ultrasound technology is capable of assessing the structure and function of the heart. The measurement of ventricular size, ventricular wall thickness, and other indices enables the diagnosis of structural abnormalities in the heart. Additionally, the assessment of myocardial contractility and diastolic function allows for the understanding of the pumping function of the heart. The heart's impairment can be determined, and the reserve function of the heart can be assessed through the measurement of parameters such as the ejection fraction. Min et al. [3] demonstrated that cardiac ultrasound can also detect valve lesions, blood flow rate and direction, and other information, thus providing comprehensive information for the diagnosis of chronic heart failure. For example, three-dimensional echocardiography technology can show the structure of the heart. Three-dimensional echocardiography technology provides a more accurate diagnosis by allowing the heart to be viewed in three dimensions. Tissue Doppler imaging technology assesses the movement of the myocardium in real time, providing a basis for the evaluation of myocardial function. Strain imaging quantitatively evaluates myocardial deformation, which provides a reliable basis for the early diagnosis of chronic heart failure.

2. Cardiac Ultrasound in the Diagnosis of Chronic Heart Failure

2.1 Structural Evaluation of the Heart

Lu et al. [4] demonstrated that in the diagnosis of chronic heart failure, it is of paramount importance to actively assess the structure of the heart. Cardiac ultrasound is a valuable tool that can clearly display the anatomical structure of the heart, thus enabling physicians to comprehend the morphology and size changes of the heart, and subsequently determine whether there are structural abnormalities.

2.1.1 Measurement of left and right ventricular size

The left and right ventricles are the primary cardiac pumping organs, and their volume is a crucial diagnostic indicator of chronic heart failure. These organs can reflect changes in the condition to some extent, and cardiac ultrasound is an accurate method for measuring the end-diastolic and end-systolic diameters and volumes of the left and right ventricles. This assessment can provide insight into the size of the ventricles. Xu et al. [5] demonstrated that in patients with chronic heart failure, the left ventricle tends to be enlarged, with the right ventricle also affected to varying degrees. These measurements can therefore be used to initially determine the condition of chronic heart failure.

2.1.2 Evaluation of ventricular wall thickness and wall motion

Ventricular wall thickness and wall motion are important indicators of myocardial condition. Cardiac ultrasound can be used to assess the thickness of the ventricular wall and the motion of the ventricular wall, which allows the physician to evaluate the degree of myocardial hypertrophy, the presence of myocardial fibrosis, and other pathological changes in the patient. Additionally, by observing the coordination of ventricular wall movement, it is possible to determine whether there are local myocardial movement abnormalities, such as ventricular wall tumor formation after myocardial infarction.

2.1.3 Detection of valvular lesions

Heart valves are essential structures for maintaining normal blood flow in the heart. Valve disease is a significant contributor to chronic heart failure. Cardiac ultrasound can provide a comprehensive assessment of valve morphology, structure, and functional status, which can assist physicians in identifying valve stenosis, insufficient closure, and other conditions. In a study by Li et al. [6], it was demonstrated that in patients with chronic heart failure, valvular lesions can exacerbate the condition. Therefore, timely detection and treatment of valvular lesions is conducive to improving the prognosis of patients with chronic heart failure.

2.2 Cardiac Function Assessment

2.2.1 Measurement of ejection fraction

Ejection fraction (EF) is a crucial indicator of cardiac function, primarily reflecting the percentage of blood pumped out of the left ventricle during each contraction as a percentage of the ventricular end-diastolic volume. Cardiac ultrasound measures LV end-diastolic and end-systolic volumes to calculate the ejection fraction. The normal value of ejection fraction is >50%, and failure to meet this criterion suggests impaired cardiac function. Sun et al. [7] demonstrated that ejection fraction tends to decrease in patients with chronic heart failure, with a greater decline observed in those with more severe disease. Therefore, ejection fraction measurement can not only diagnose heart failure but also assess its severity.

2.2.2 Myocardial systolic and diastolic

Myocardial systolic and diastolic properties are primarily indicative of cardiac function.

Cardiac ultrasound technology enables the assessment of myocardial systolic and diastolic properties by observing myocardial movement and deformation. In patients with chronic heart failure, the contractility and diastolic properties of the heart muscle are frequently impaired, resulting in a reduction in the pumping function of the heart. Through cardiac ultrasound, physicians can observe the velocity of myocardial movement and thus determine the contractility of the myocardium. Wang et al. [8] demonstrated that by evaluating myocardial contractility and diastolic properties, physicians can gain a comprehensive understanding of the functional state of the heart in patients with chronic heart failure, which can inform the development of personalized treatment plans.

2.2.3 Assessment of cardiac reserve function

Cardiac ultrasound technology can be employed to assess changes in the function of the heart in different states, thereby enabling the assessment of cardiac reserve function. For instance, following the administration of medication or the performance of exercise, cardiac ultrasound can observe alterations in heart rate, myocardial contractility, and other indicators, thus allowing for the assessment of the heart's reserve capacity. Zhang et al. [9] demonstrated that cardiac ultrasound can also be utilized to assess the volume reserve of the heart by measuring the changes in ventricular end-diastolic volume. By assessing cardiac reserve function, physicians can ascertain the cardiac responsiveness of patients with chronic heart failure and subsequently optimize the treatment plan. For instance, in patients with poor cardiac reserve function, the use of medication should be avoided to prevent the use of drugs that are more stimulating to the heart, thus avoiding further deterioration of the condition.

2.3 Hemodynamic Assessment

The primary objective of hemodynamic assessment is to gain insight into the status of blood flow within the heart, thereby enabling the determination of the severity and etiology of heart failure.

2.3.1 Blood flow velocity and direction measurement

Cardiac ultrasound is a non-invasive imaging technique that can accurately measure the speed and direction of blood flow in the heart. With color Doppler ultrasound technology, physicians can view real-time dynamic images of blood flow in the heart to determine whether the blood flow is smooth and unobstructed, or if there are any abnormalities such as regurgitation or eddy currents. Patients with chronic heart failure often experience slowed blood flow or even regurgitation as a result of decreased heart pumping, and these abnormal blood flow patterns can be used to diagnose heart failure.

2.3.2 Pressure gradient calculation

The pressure gradient is the difference in pressure between different parts of the heart, which reflects the resistance to blood flow in the heart. With cardiac ultrasound technology, physicians can measure the pressure values in different parts of the heart and then calculate the corresponding pressure gradient. In patients with chronic heart failure, the pressure gradient is abnormal due to myocardial damage and ventricular remodeling, so the pressure gradient can be calculated to assess the condition of the heart failure.

2.3.3 Assessment of blood flow resistance and compliance

Blood flow resistance and compliance are indicators of the hemodynamic status of the heart. Typically, blood flow resistance is influenced by the internal diameter of blood vessels, blood flow rate, and blood viscosity, while compliance is related to the elasticity of the heart and blood vessels. Cardiac ultrasound can detect the resistance and compliance of the heart and blood vessels, thus helping physicians to understand the heart's ability to respond when stimulated. In patients with chronic heart failure, blood flow resistance and compliance are abnormal due to factors such as myocardial damage and hardening of blood vessels. These abnormalities not only affect the pumping function of the heart, but also lead to worsening of the symptoms of heart failure. Therefore, assessing blood flow resistance and compliance through cardiac ultrasound can help physicians to formulate an accurate treatment plan and improve the prognosis of patients with chronic heart failure.

3. The Value of Cardiac Ultrasound in the Evaluation of Cardiac Function in Chronic Heart Failure

3.1 Assessing the Severity and Staging of

Heart Failure

Cardiac ultrasound is a non-invasive imaging technique that allows for the assessment of a number of parameters, including heart size, wall thickness, and myocardial contractility and diastolic properties. These parameters are used to evaluate the severity of chronic heart failure. For instance, left ventricular enlargement and wall thinning are indicative of severe heart failure, while ejection fraction measurements can be used to determine the severity of heart failure by understanding the degree of decline in the heart's pumping function. In addition, ultrasound parameters can be combined with other imaging techniques to stage heart failure.

3.2 Predicting Prognosis in Heart Failure Patients

Patients with lower ejection fraction are typically associated with a worse prognosis, with an increased risk of cardiovascular events and mortality. Cardiac ultrasound is a valuable tool for assessing myocardial contractility and diastolic properties, which can determine myocardial reserve capacity and adaptive capacity. This, in turn, can inform the prognosis for the patient.

3.3 Guiding Therapeutic Decisions in Heart Failure Patients

Cardiac ultrasound can assess the structural and functional status of the heart and guide the physician in selecting appropriate therapeutic drugs and cardiac rehabilitation methods for the patient. For example, for patients with low ejection fraction, doctors may consider using drugs to enhance myocardial contractility, while for patients with diastolic dysfunction, the treatment plan may need to be adjusted to improve myocardial diastolic function. In addition, cardiac ultrasound can monitor changes in condition during treatment and provide a basis for physicians to adjust treatment plans.

3.4 Monitoring Patient Outcomes in Heart Failure

Cardiac ultrasound is also of great value in monitoring the therapeutic effects of heart failure patients. By carrying out regular cardiac ultrasound examinations, clinicians can fully understand the structural and functional changes of the patient's heart, so as to assess the therapeutic effects. For example, a gradual improvement in ejection fraction and improvement in ventricular wall motion during treatment would indicate a favorable outcome. Conversely, if the cardiac ultrasound parameters do not demonstrate a significant improvement or deterioration, it suggests that the treatment is ineffective and that the treatment program requires adjustment. Lu et al. [10] demonstrated that by actively monitoring cardiac ultrasound during the treatment of heart failure patients, problems in the treatment can be identified in a timely manner, allowing for the implementation of corresponding improvement measures, ultimately improving the treatment effect of the disease.

4. Advances in New Cardiac Ultrasound Techniques

The continuous development of medical technology has led to the gradual introduction of a greater variety of cardiac ultrasound techniques, with three-dimensional echocardiography being a notable example.

4.1 3D Echocardiography

Three-dimensional echocardiography is a technique that employs computerized image reconstruction to generate a three-dimensional image of the heart by acquiring two-dimensional ultrasound images of multiple sections of the heart. This technique enables the visualization of the heart's structure, thereby providing physicians with more comprehensive information for the diagnosis of cardiac conditions. In comparison to the traditional two-dimensional echocardiogram, the three-dimensional echocardiogram exhibits superior spatial resolution, enabling more precise assessment of the size, shape, thickness, and movement of the heart muscle. Additionally, three-dimensional echocardiograms permit observation of the heart's movement during different cardiac cycles, facilitating more accurate assessment of the systolic and diastolic properties of the heart.

In the diagnosis of chronic heart failure, three-dimensional echocardiography can assess the overall structure of the heart and observe whether the heart appears to be enlarged or deformed. This allows for the determination of whether there is the occurrence of heart failure conditions. Additionally, three-dimensional echocardiography can accurately measure the thickness and movement of the heart muscle, which can assist physicians in assessing the contractility and diastolicity of the heart muscle. This, in turn, allows for the determination of the severity of heart failure.

4.2 Doppler Imaging of Tissue

Tissue Doppler imaging assesses myocardial function by capturing the signals of small movements of myocardial tissue. This technique provides a real-time, dynamic display of myocardial motion, allowing physicians to view subtle changes in the myocardium during different cardiac cycles. Secondly, tissue Doppler imaging can also provide quantitative parameters of myocardial motion, such as myocardial velocity and acceleration, to help doctors accurately assess myocardial function.

5. Conclusion

In conclusion, cardiac ultrasound has significant diagnostic value in the assessment of patients with chronic heart failure. It can accurately measure the size of the ventricle, ventricular wall thickness, valve function, and other cardiac parameters, which can inform the diagnosis of chronic heart failure. Furthermore, with the ongoing advancement of ultrasound technology, the integration of new techniques such as three-dimensional echocardiography and tissue Doppler imaging will enhance the diagnostic capabilities of cardiac ultrasound.

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