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Real-time Shear Wave Elastography Assessment of Muscle Elasticity in Patients with Renal Failure

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Abstract: *Objective:* To explore the value of real-time elastic shear wave in evaluating muscle elasticity in patients with renal failure. *Methods:* 50 patients with chronic renal failure from January 2019 to December 2022 were randomly selected as the experimental group, and 50 healthy patients aged 21–61 during the same period were selected as the control group, and the basic information of the patients, including age, gender, body mass index, etc., were collected. Besides, the Young's modulus of the two groups of patients were observed and analyzed. *Results:* The Young's modulus values of left and right gastrocnemius muscles in the experimental group were significantly lower than those in the control group ($P < 0.05$), and there was no statistical difference between the left and right sides of the experimental group and the control group ($P > 0.05$). *Conclusion:* Real-time shear wave elastography provides a non-invasive, real-time and effective tool for the assessment of muscle elasticity in patients with renal failure. Through further research and optimization, real-time shear wave elastography will play a greater role in the prevention and treatment of patients with renal failure, improving the quality of life and prognosis of patients.

Keywords: Real-time shear wave elastography; Renal failure; Muscle elasticity

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1. Introduction

Renal failure is a systemic disease characterized by the accumulation of metabolites caused by renal dysfunction and electrolyte and water imbalance, which lead to multisystem illnesses [1]. Muscle relaxation is one of the common complications in patients with renal failure [2]. Muscle relaxation not only affects the quality of life of patients, but may also lead to other serious complications, such as muscle atrophy, arthritis, and osteoporosis [3]. Therefore, assessment of muscle elasticity in patients with renal failure is of great significance for the prevention and treatment of these complications. Real-time shear wave elastography is a non-invasive ultrasound technique that can rapidly and non-invasively assess tissue elasticity [4-7]. Its principle involves using the velocity and amplitude changes of ultrasonic waves propagating in the tissue to calculate the elastic coefficient of the tissue, so as to determine the elasticity of the tissue. In patients with renal failure, real-time shear wave elastography can be employed to evaluate muscle elasticity and identify potential complications such as muscle relaxation.

2. Materials and methods

2.1. General information

Fifty chronic renal failure patients aged 20–65 were randomly selected between January 2019 and December 2022, comprising 25 males and 25 females, for the experimental group. Concurrently, 50 healthy individuals aged between 21 and 61 during the same period were chosen as the control group, consisting of 27 males and 23 females. Basic patient information, encompassing age, gender, body mass index, and medical history, was collected.

Table 1. General information of the patients

Item		Experimental	Control group	t/X^2	P
Number of cases		50	50	-	-
Age(years)		41. 10 ± 1 2.22	40. 46 ± 8.17	0. 308	0. 759
Age range (years)		20-65	21-61	-	-
BMI		21. 00 ± 5.91	21.0 4 ± 4.56	0. 038	0.970
Gender	Male	25 (50.00)	27 (54.00)	0.1603	0.6889
	Female	25 (50.00)	23 (46.00)		

2.2. Methods

Elastography Ultrasonic Muscle Tester (USA): This instrument evaluates the elasticity and deformation of muscles through real-time elastography. At the same time, the instrument has high resolution, low noise, and is easy to operate. It is suitable for research in the fields of muscle injury and rehabilitation medicine.

The required equipment and materials were readied, encompassing an ultrasound probe, gel, tissue, measuring ruler, and more. The patient was positioned laterally, with the leg to be assessed extended outside the bed. The ultrasound probe (applied with gel) was positioned on the skin at the midpoint of the calf's dorsal side, aligned parallel to the calf's long axis. The ultrasound instrument was activated, and the parameters were adjusted to a suitable setting. Real-time shear waves were directed toward the calf, with the ultrasonic image observed. The distance and time of shear wave propagation were measured and recorded, facilitating the calculation of shear wave velocity. These steps were repeated, measuring during both muscle relaxation and muscle contraction. The measurement outcomes, including muscle elastic coefficient and muscle thickness, were analyzed and recorded. The equipment and materials were arranged to conclude the measurement process.

2.3. Observation indicators

The Young's modulus of the two groups of patients was observed and analyzed. Young's modulus is a physical quantity that describes the ability of a solid material to resist deformation. It is defined as the property of a material to resist stress when stretched or compressed, and is a measure of the material's modulus of elasticity. The definition of Young's modulus is $E = \sigma/\varepsilon$, where E represents Young's modulus, σ represents stress, and ε represents strain. The Young's modulus reflects the elastic properties of the material when it is stretched or compressed. When stress and strain are linearly related, Young's modulus is equal to stress divided by linear strain. In most cases, the relationship between stress and strain in a material is nonlinear, so Young's modulus corresponds to only a part of the elastic properties of the material. Young's modulus is widely used in materials science and engineering to calculate the strength, stiffness, and deformation properties of materials, and it can also be used to evaluate the processing performance and applicability of materials. For example, in structural design, component design, metal processing, etc., the Young's modulus of a material needs is calculated to determine the applicability and strength of the material.

2.4. Statistical analysis

The data analysis was conducted using SPSS 24.0. Measurement data were presented as mean ± standard deviation and analyzed using a *t*-test. Count data were presented as rates (%) and analyzed using a x^2 test. A significance level of $P < 0.05$ was applied to determine statistical significance.

3. Results

The Young's modulus values of left and right gastrocnemius muscles in the experimental group were significantly lower than those in the control group ($P < 0.05$), and there was no statistical difference between the left and right sides of the same group ($P > 0.05$), as shown in **Table 2**.

Table 2. Comparison of Young's modulus values between the two groups of patients (kPa)

Group	Experimental group (*n* = 50)	Control group (*n* = 50)	*t*	*P*
Left side	60. 22 ± 5.21	98.72 ± 8.70	26.830	0.0000
Right side	61.46 ± 4.13	97 .1 8 ± 4.04	43.662	0.0000
t	1.317	0.3262	-	-
P	1.135	0.260	-	-

4. Discussion

Renal failure can be detrimental to a patient's muscle elasticity as it leads to impaired excretion of metabolic waste and water. As renal function declines, patients may experience generalized edema and decreased muscle elasticity. Changes in muscle elasticity are mainly manifested in symptoms such as muscle relaxation, weakness, and muscle atrophy. These symptoms can lead to decreased exercise capacity and limitations in daily life and the need for rehabilitation. The changes in muscle elasticity vary with individual differences, but generally show a gradual downward trend. As the disease progresses, the patient's muscles and muscle strength will gradually reduce [8-10]. In this case, active treatment and management will be needed, including drug therapy, diet adjustment, and exercise program, to improve muscle elasticity and exercise capacity, and improve quality of life.

Real-time shear wave elastography assesses muscle elasticity based on ultrasound propagation in muscle tissue. Muscles exhibit elasticity, which means they deform and rebound when subjected to external force. This method measures the speed and direction of ultrasonic waves in muscle tissue to evaluate muscle elasticity and deformation properties. In this method, the muscle tissue is first scanned with an ultrasonic probe and an acoustic wave image of the muscle tissue is obtained; then, by sending a shear wave into the muscle tissue, an echo signal of the shear wave is received by an ultrasound receiver. Due to the different elasticity of muscle tissue, the speed of shear wave propagation in muscle tissue will also be different. By measuring the propagation speed and direction of the shear wave in the muscle tissue, the elastic coefficient and deformation characteristics of the muscle tissue can be calculated. Real-time shear wave elastography assessment of muscle elasticity is non-invasive, has high-resolution, and it can provide real-time results. Through this method, the elasticity and deformation characteristics of muscle tissue can be quickly and accurately evaluated, which is of great significance for the diagnosis and treatment of muscle injuries and the evaluation of the effect of sports training [11-15]. However, it should be noted that the accuracy of real-time shear wave elastography by many factors, such as the pressure of the probe, scanning depth, and muscle state, etc., which need to be strictly controlled during the assessment process.

This study's results indicate that real-time shear wave elastography is effective in assessing muscle elasticity among patients with renal failure. Muscle elasticity is notably reduced in patients with renal failure compared to healthy individuals. Furthermore, real-time elastic shear waves can identify early muscle relaxation, offering a foundation for prompt intervention and treatment.

Real-time shear wave elastography have broad application prospects in the assessment of muscle elasticity in patients with renal failure.

Firstly, it aids in the identification of issues like muscle relaxation, enabling timely interventions to avert disease progression. Secondly, this method offers a direction for treatment, including tailored exercise rehabilitation plans to enhance muscle function in patients. However, real-time elastic shear waves still possess limitations when assessing muscle elasticity in renal failure patients, such as susceptibility to factors like patient obesity and subcutaneous edema. Further research and refinement of techniques are necessary.

Real-time shear wave elastography is a non-invasive method for evaluating muscle elasticity. The elastic and deformation properties of muscle tissue can be quickly and accurately evaluated through the transmission and deflection of shear waves. The development of real-time elastic shear wave technology has gone through several stages. The earliest real-time elastic imaging technology can be traced back to the 1990s. Real-time elastography continues to improve in accuracy and resolution, making it an important tool for muscle assessment.

The development of real-time elastic shear wave technology is mainly affected by the following aspects:

(1) Ultrasonic technology: Real-time elastography is evaluated based on the propagation of ultrasound waves in muscle tissue, so the development of ultrasonic technology has an important impact on the accuracy and resolution of real-time elastic shear wave technology.

(2) Computer technology: Ultrasonic signals are converted into digital signals for complex data processing and analysis. Therefore, the development of computer technology has an important impact on the accuracy and reliability of real-time shear wave elastography.

(3) Application fields: Real-time shear wave elastography is widely used in sports physiology, rehabilitation medicine, muscle injury and other fields. With the continuous development and expansion of these fields, real-time elastic shear wave technology will also be continuously improved and optimized.

Future research directions include comparative studies of muscle elasticity changes in patients with renal failure at different stages, and the evaluation and application of real-time shear wave elastography in other chronic diseases. In addition, through large-scale clinical trials, the sensitivity and specificity of real-time shear wave elastography in the assessment of muscle elasticity in patients with renal failure were verified, providing strong support for its wide application in clinical practice.

5. Conclusion

In conclusion, real-time shear wave elastography provide a noninvasive, real-time, and effective tool for the assessment of muscle elasticity in patients with renal failure. Through further research and optimization, this method will play a greater role in the prevention and treatment of patients with renal failure, improving the quality of life and prognosis of patients.

Disclosure statement

The authors declare no conflicts of interest.

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