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Original Article

Clinical value of three-dimensional speckle tracking echocardiography in evaluating left ventricular function in maintenance hemodialysis patients

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Abstract: Objective: To explore the value of real-time three-dimensional speckle tracking imaging (RT3D STI) in evaluating left ventricular function in maintenance hemodialysis patients. Methods: Eighty patients with maintenance hemodialysis were recruited in this retrospective study, which were divided into observation group 1 (35 cases, dialysis for 6-12 months) and observation group 2 (45 cases, dialysis for at least 12 months). At the same time, 40 healthy medical examiners were selected as the control group. All the patients received two-dimensional (2D) echocardiography and RT3D-STI to measure left ventricular function. Results: Systolic blood pressure, diastolic blood pressure, triglyceride, total cholesterol, low-density lipoprotein, high-density lipoprotein, hemoglobin, serum creatinine and urea nitrogen were statistically different among the three groups ($P<0.05$). There were no significant differences in age, gender, body mass index and blood glucose among the three groups ($P>0.05$); there was no significant difference in above parameters between the two observation groups ($P>0.05$). The 2D echocardiographic parameters (LVDd, IVSd, LVPWd, LVESV, LVEDV, SV, LVEF) of the three groups were statistically different ($P<0.05$). The LVDd, IVSd, LVPWd, LVESV, LVEDV and SV of the two observation groups were higher than those of the control group ($P<0.05$), while the LVEF was lower than that of the control group ($P<0.05$); there was no significant difference in above parameters between the two observation groups ($P>0.05$). The parameters of RT3D-STI were compared between the three groups: the LVEVD and LVESV of two observation groups were higher than those of the control group, while the LVEF was lower than that of the control group ($P<0.05$); the LVEVD and LVESV of observation group 1 were higher than those of observation group 2, and LVEF was lower than that of observation group 2 ($P<0.05$). The GLS, GCS, GAS and GRS of the two observation groups were higher than those of the control group, which in the observation group 1 were higher than those of observation group 2 ($P<0.05$). Conclusion: Real-time three-dimensional speckle tracking imaging can accurately assess left ventricular function in hemodialysis patients, and long-term hemodialysis can improve cardiac function to a certain extent.

Keywords: Real-time three-dimensional speckle tracking imaging (RT3D STI), maintenance hemodialysis, left heart function, evaluation value

Introduction

With the progress and development of society, incidence of chronic kidney disease (CKD) is also increasing year by year which is now as high as 11%, due to various factors such as diet structure, exercise habits, environmental changes, and accelerated aging [1]. Meanwhile, the number of patients in end-stage renal disease (ESRD) and the incidence of cardiovascular disease are also increased [2]. The treatment of ESRD patients is mainly to select the appropriate alternative therapy for different patients, including hemodialysis (HD), peritoneal dialysis or kidney transplantation [3]. More than 2 million people worldwide need alternative treatments every year, and by the year of 2030, it is estimated that there are about 5.4 million hemodialysis patients worldwide [4]. Due to the limitations of the national economy and the limited number of donated kidneys, the current treatment of ESRD in China is mainly based on maintenance hemodialysis [5]. Researchers found that the most common cause of death in patients with maintenance hemodialysis is cardiovascular events, of which myocardial infarction is the most common one, accounting for about 50% [6, 7]. In addition, early prediction of cardiovascular events and active intervention have a positive effect on the prognosis of patients. Hemodialysis patients have myocardial injury in the early stage but no clinical symptoms and signs. Therefore, it is of great significance to diagnose the myocardial injury as early as possible and adopt active intervention to prognosis [8].

Previous studies have shown that myocardial deformation dysfunction has occurred before the patient's cardiac structure changes [9], and patients with left ventricular dysfunction have a higher prevalence and mortality [10, 11]. The gold standard for the diagnosis of cardiovascular disease is coronary angiography in clinic. Although coronary angiography can make a clear judgment on the extent and location of coronary stenosis, the myocardial systolic and diastolic function caused by myocardial injury in the case of myocardial ischemia and hypoxia cannot be accurately evaluated by coronary angiography and conventional echocardiography [12, 13]. Real-time three-dimensional speckle tracking imaging (RT3D-STI) is a new technique for evaluating left ventricular mechanical characteristics in recent years, which can evaluate early myocardial damage in the left ventricle with reliable results and high accuracy [14, 15]. Therefore, this study adopted RT3D-STI to evaluate the myocardial strain, torsional motion and contraction of the left ventricle in hemodialysis patients, so as to explore the application value of RT3D-STI in the evaluation of left ventricular function in maintenance hemodialysis patients.

Materials and methods

Subjects and grouping

This retrospective study recruited 80 patients with maintenance hemodialysis admitted to the Department of Nephrology from May 2019 to July 2019 in Meizhou People's Hospital, including 49 males and 31 females, aged 40-80 years, with an average age of 62.5±8.2 years. These patients were divided into observation group 1 (35 cases, dialysis for 6-12 months) and observation group 2 (45 cases, dialysis for at least 12 months). At the same time, 40 healthy medical examiners in our hospital were selected as the control group, with an average age of 64.3±7.6 years. Informed consent was signed for all of the above patients and the study was approved by the Ethics Committee of Meizhou People's Hospital.

Inclusion and exclusion criteria

Inclusion criteria: (1) maintenance hemodialysis for more than 6 months; (2) age over 18 years old; (3) blood biochemistry and height, weight, and blood pressure were examined one week before RT3D-STI; (4) patients undergoing B-ultrasound examination of the carotid artery.

Exclusion criteria: (1) patients with incomplete clinical data; (2) patients with severe malnutrition, tumors, etc.; (3) patients with mental disorders or cerebrovascular diseases; (4) patients with primary cardiac disease such as massive pericardial effusion, rheumatic heart disease or congenital heart disease; (5) patients who are poorly imaged due to obesity and organ interference.

Methods

Baseline data and color ultrasound data were derived from the His electronic case system of the hospital, and statistical analysis was performed. The color Doppler ultrasound measurement index refers to the cardiac cavity quantitative guide [16].

Two-dimensional (2D) echocardiography used the cardiac color Doppler (Philips Medical Systems, USA) to detect left ventricular end-diastolic diameter (LVDd), interventricular septum thickness at end-diastolic (IVSd), and left ventricular posterior wall thickness at end-diastolic (LVPWd). Left ventricular end-systolic volume (LVESV), left ventricular end-diastolic volume (LVEDV), stroke volume (SV) and left ventricular ejection fraction (LVEF) were measured by the dual plane Simpson method.

RT3D-STI used Philips i E33 color Doppler ultrasound system (Philips Medical Systems, USA), with probe S5-1 and 3D strain software at the frequency of 1-5 MHz, to detect LVEDV, LVESV and LVEF, collect the "bull eye" diagram and strain-time curves at 17-segment to record the global longitudinal strain (GLS), global circumferential strain (GCS), global area strain (GAS) and global radial strain (GRS).

Table 1. Baseline data

	Control group	Observation group 1	Observation group 2	χ^2/F	P
Gender (male/female)	22/18	21/14	28/17	0.471	0.790
Age (year)	64.4±7.7	63.5±8.0	62.3±8.9	0.717	0.490
Systolic blood pressure (mmHg)	108.55±5.89	152.63±7.13*	151.78±8.20*	491.452	<0.001
Diastolic blood pressure (mmHg)	68.42±5.14	88.80±6.57*	87.78±8.20*	112.332	<0.001
Triglyceride (mmol/L)	1.14±0.71	1.83±0.64*	1.74±0.64*	12.396	<0.001
Total cholesterol (mmol/L)	4.56±0.42	5.86±0.44*	5.88±0.41*	128.966	<0.001
High density lipoprotein (mmol/L)	1.53±0.42	1.13±0.36*	1.08±0.34*	17.577	<0.001
Low density lipoprotein (mmol/L)	2.43±0.41	3.80±0.88*	3.86±0.82*	49.285	<0.001
Hemoglobin (gl/L)	131.38±9.67	103.978±9.18*	101.49±10.86*	111.165	<0.001
Body mass index (BMI) (kg/m^2)	26.81±2.14	27.32±2.23	26.95±2.14	0.556	0.575
Blood sugar (mmol/L)	5.71±0.79	5.62±0.77	5.55±0.77	0.499	0.608
Urea nitrogen (mmol/L)	5.86±0.42	18.03±0.64*	17.94±0.64*	5918.602	<0.001
Serum creatinine (umol/L)	89.13±1.53	693.07±223.25*	688.24±220.62*	146.990	<0.001

Note: Compared with the control group, *P<0.05.

Statistical analysis

SPSS 17.0 software (Asia Analytics Formerly SPSS, China) was used for statistical analysis. Continuous variables were expressed as mean ± standard deviation ($\overline{x}$ ± sd), and variables that conformed to normal distribution and homogeneity of variance were analyzed by independent sample t test; multiple sets of comparisons were analyzed using one-way analysis of variance, and if there were differences, further comparisons were made using LSD analysis. The count data is expressed as number of cases/percentage (n/%) and analyzed by Pearson chi-square test and Fisher exact probability method. P<0.05 was considered statistically different.

Results

Comparison of general and baseline data

Systolic blood pressure, diastolic blood pressure, triglyceride, total cholesterol, low-density lipoprotein, high-density lipoprotein, hemoglobin, serum creatinine and urea nitrogen were statistically different among the three groups (P<0.05). There were no significant differences in age, gender, body mass index (BMI) and blood glucose among the three groups (P>0.05). There was no significant difference between the two observation groups (P>0.05). See **Table 1**.

Comparison of two-dimensional echocardiographic parameters

The 2D echocardiographic parameters (LVDd, IVSd, LVPWd, LVESV, LVEDV, SV, LVEF) of the three groups were statistically different (P<0.05). The LVDd, IVSd, LVPWd, LVESV, LVEDV and SV of the two observation groups were higher than those of the control group (P<0.05), while the LVEF was lower than that of the control group (P<0.05). There was no significant difference between the observation group 1 and group 2 (P>0.05). See **Table 2**.

Comparison of RT3D-STI parameters

Parameters of 3D echocardiographic were compared among three groups of patients. The LVEVD and LVESV of the two observation groups were higher than those of the control group, while the LV-EF was lower than that of the control group (P<0.05). The LV-EVD and LV-ESV of the observation group 1 were higher than that of observation group 2, and LV-EF was lower than that of observation group 2 (P<0.05). See **Table 3**; **Figure 1**.

The GLS, GCS, GAS and GRS of observation group 1 and group 2 were higher than those of the control group (P<0.05). The GLS, GCS, GAS and GRS of group 1 were higher than those of group 2 (P<0.05). See **Table 4**.

In **Figure 2A, 2B**, a male patient in the observation group who underwent maintenance hemo-

Table 2. Left ventricular function detected by two-dimensional chocardiographic parameters

	Control group (n=40)	Observation group 1 (n=35)	Observation group 2 (n=45)	F	P
LVDd (mm)	46.15±3.82	55.01±5.61*	54.13±6.27*	32.698	<0.001
IVSd (mm)	9.21±0.87	12.04±2.11*	11.71±2.36*	25.802	<0.001
LVPWd (mm)	9.15±7.30	12.18±2.00*	11.87±2.24*	34.166	<0.001
LVESV (mL)	31.63±9.12	59.68±20.82*	56.83±22.51*	27.310	<0.001
LVEDV (mL)	97.82±21.64	142.79±34.01*	137.46±38.05*	134.013	<0.001
SV (mL)	73.84±9.53	91.50±23.03*	87.89±25.76*	7.80	0.001
LVEF (%)	66.92±6.14	62.13±6.88*	61.05±7.69*	8.246	<0.001

Note: Compared with the control group, *P<0.05. LVDd: left ventricular end-diastolic diameter; IVSd: interventricular septum thickness at end-diastolic; LVPWd: left ventricular posterior wall thickness at end-diastolic; LVESV: left ventricular end-systolic volume; LVEDV: left ventricular end-diastolic volume; SV: stroke volume; LVEF: left ventricular ejection fraction.

Table 3. Left ventricular function detected by three-dimensional speckle imaging techniques

	Control group (n=40)	Observation group 1 (n=35)	Observation group 2 (n=45)	F	P
LVEVD (mL)	84.42±20.64	115.68±36.67***	101.18±35.07***,#	9.231	<0.001
LVESV (mL)	33.67±10.72	63.85±27.04***	53.77±23.43***,#	20.131	<0.001
LVEF (%)	71.81±12.29	47.62±13.62***	53.41±12.08***,#	38.807	<0.001

Note: Compared with the control group, ***P<0.001. Compared with the observation group 1, #P<0.05. LVEVD: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; LVEF: left ventricular ejection fraction.

dialysis for 2 years, who is 54 years old, with primary disease of chronic nephritis, no previous history of hypertension, diabetes, stable dialysis, good weight control, and negative physical examination, no lower extremity edema. In **Figure 2C, 2D**, the subject from the control group was a healthy medical examiner, male, 48 years old, with physical health and no positive signs. In the observation group, the RT3D-STI of the patients showed a decrease in EF value compared with healthy control, and the left ventricular systolic end-diastolic volume has been expanded.

Discussion

The main cause of death in HD patients is cardiovascular diseases [5, 6]. Incidence of hyperphosphatemia induced cardiovascular events is increased in uremic patients due to disorders of calcium and phosphorus metabolism [17]. Patients with uremia often have hyperparathyroidism. Studies have found that parathyroid hormone is an independent risk factor for the cardiovascular system, of which the mechanism is related to the reduction of blood calcium caused by the inhibition of the absorption of active vitamin D [18]. Hemodialysis also causes damage to the myocardium, such as changes in hemodynamics during dialysis, the use of anticoagulants, the occurrence of micro inflammation in the body, and inadequate dialysis leading to the accumulation of toxins that affect heart function and cause damage [19, 20].

RT3D-STI is a new type of ultrasound technology. It has been found that it can better evaluate the systolic and dysfunction after early heart injury and the results are accurate and sensitive [21, 22]. In the study of atrial fibrillation, apnea syndrome and other diseases, the use of RT3D-STI can achieve a good evaluation of cardiac systolic and diastolic function [23, 24].

Previous studies have reported that echocardiographic abnormalities in hemodialysis patients are closely related to their prognosis, and are more closely than traditional risk factors such as hypertension, obesity, smoking, etc. [25]. Myocardial injury in patients with uremia is mainly characterized by left ventricular thickening and increased left ventricular mass index [26], which are independent risk factors for cardiovascular events [27]. In our study, 2D echocardiographic results between hemodialysis patients and normal people were compared and the results reveal that the cardiac structural parameters of hemodialysis patients were increased. Although the left ventricular ejection

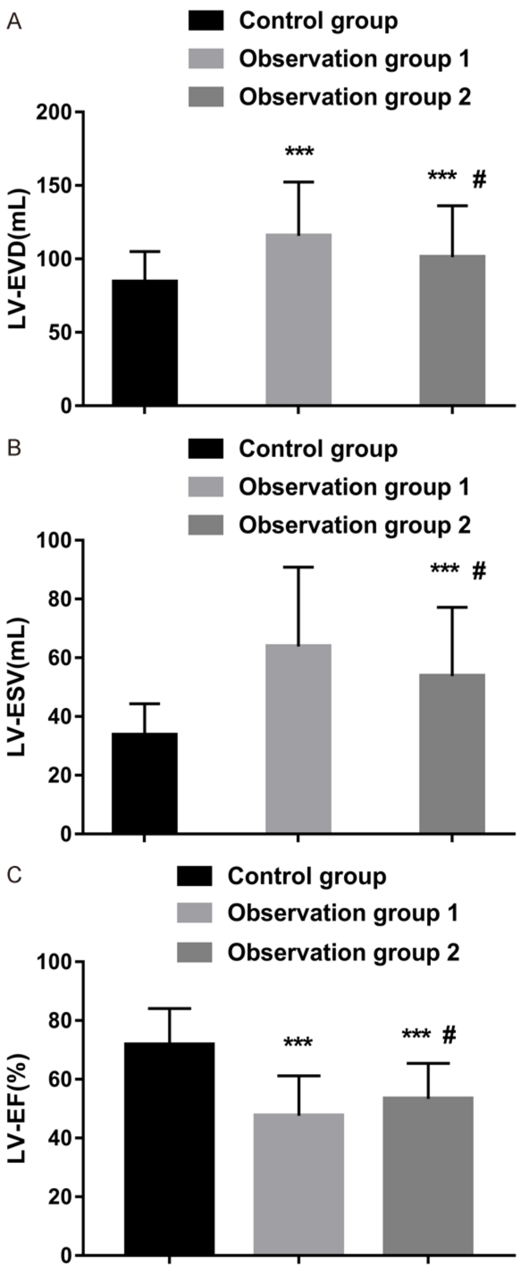

Figure 1. Left ventricular function detected by three-dimensional echocardiographic parameters. A. LVEVD level; B. LVESV level; C. LV-EF level. Compared with the control group, ***P<0.001. Compared with the observation group 1, $^{\#}$P<0.05. LVEDV, left ventricular end-diastolic volume; LVESV, left ventricular end-systolic volume; LVEF, left ventricular ejection fraction.

fraction of hemodialysis patients is in the normal range, it is still lower than that of normal people, indicating that the left ventricle of hemodialysis patients has changed accordingly.

The study further used three-dimensional ultrasound to evaluate the left ventricular structure and left ventricular ejection fraction of all the subjects and the results showed that the left ventricular end-systolic volume and end-diastolic volume of hemodialysis patients were significantly larger than normal, and the increase in left ventricular end-systolic volume and end-diastolic volume was more remarkable in patients with a hemodialysis period of 6-12 months. Moreover, hemodialysis patients also showed a decrease in left ventricular ejection fraction, which was more significant than those measured by 2D echocardiography, and the decrease of left ventricular ejection fraction was more obvious in patients with hemodialysis for 6-12 months, which may be caused by the relatively poor toxin clearance in the early hemodialysis of the patient, as well as the retention of water in the body, and the dry weight is not up to standard [17, 18].

In the measurement of myocardial longitudinal and circumferential stratified strain parameters by RT3D-STI, the myocardial contraction ability in the endocardium is stronger than that of the epicardium, and the muscles in the endocardium are mostly longitudinal muscles, which are more sensitive to blood ischemia and hypoxia, thus, the early myocardial damage in the disease is mostly the reduction of longitudinal strain [28]. In 2015, the American Society of Echocardiography (ASE) modified the reference value for the left ventricular GLS to be -20% in the revised Cardiac Quantitative Guide. A previous study included 182 patients with chronic kidney disease, 116 of whom were hemodialysis patients and were followed up for 7.8 years. Eventually, 112 patients died and 41% of all causes were cardiovascular events. The study also found that GLS is an independent risk factor for cardiovascular events, with a predictive value of >-16% [29]. Another study found that hemodialysis patients had lower GLS, GCS, GAS, GRS, and strain rates than normal people, and the authors further found that hemodialysis patients had higher GLS, GCS, GAS, GRS and strain rates than those with chronic kidney disease but not dialysis [30]. Our study found that GLS, GCS, GAS, and GRS in hemodialysis patients were higher than normal, indicating that their strain capacity decreased. Furthermore, patients with hemodialysis for 6-12 months had higher GLS, GCS, GAS, and GRS than those with dialysis for more than 12

Table 4. Strain parameter detected three-dimensional speckle imaging techniques

	Control group (n=40)	Observation group 1 (n=35)	Observation group 2 (n=45)	F	P
GLS (%)	-19.18±4.35	-12.61±3.68*	-14.29±2.78$^{*,\#}$	34.208	<0.001
GCS (%)	-18.45±4.27	-13.19±4.72*	-15.80±4.45$^{*,\#}$	12.934	<0.001
GAS (%)	-31.62±5.62	-22.13±5.56*	-25.56±5.92$^{*,\#}$	26.852	<0.001
GRS (%)	-55.85±14.71	-31.47±12.44***	-39.12±12.42$^{***,\#}$	33.984	<0.001

Note: Compared with the control group, *P<0.05, ***P<0.001. Compared with the observation group 1, $^{\#}$P<0.05. GLS: global longitudinal strain; GCS: global circumferential strain; GAS: global area strain; GRS: global radial strain.

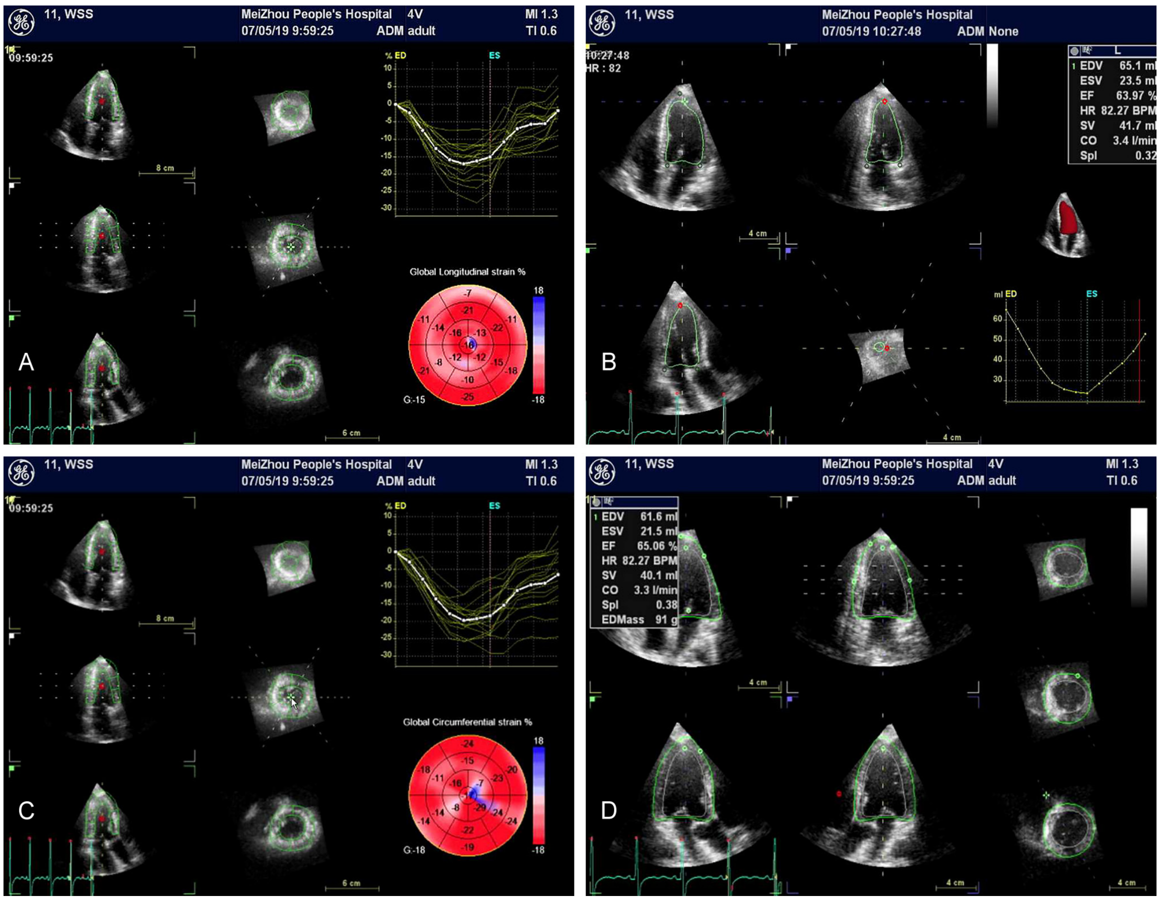

Figure 2. Typical and representative images. (A and B) are typical and representative images of the three-dimensional speckle tracking imaging of the observation group. (C and D) are typical and representative images of three-dimensional speckle tracking imaging in healthy controls.

months, which was associated with early poor hemodialysis toxin clearance, consistent with the above studies.

In conclusion, RT3D-STI can accurately assess left ventricular function in hemodialysis patients, and long-term hemodialysis can improve cardiac function to a certain extent. However, the sample size of this study is small, which can be further expanded for a multi-center research in the future.

Disclosure of conflict of interest

None.

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