Xia and Liu *BMC Cardiovascular Disorders* (2025) 25:33
https://doi.org/10.1186/s12872-025-04482-5

BMC Cardiovascular Disorders

RESEARCH

Open Access

The value of lung ultrasound score combined with echocardiography in assessing right heart function in patients undergoing maintenance hemodialysis and experiencing pulmonary hypertension

Ying Xia[1] and Xin Liu[1*]

Abstract

Aims This study explores the clinical application of lung ultrasound scoring(LUS) combined with echocardiography in assessing right heart function in patients undergoing maintenance hemodialysis(MHD) and those with elevated pulmonary artery systolic pressure(PASP), as well as the correlation between LUS and right ventricular(RV) function.

Methods Eighty five patients who underwent MHD combined with elevated PASP, at the First Central Hospital of Baoding City were selected. Divided into three groups based on PASP, and perform echocardiography and lung ultrasound examinations. Compare the right heart function parameters and LUS among the three groups. Using Pearson correlation analysis to examine the relationship between LUS and right heart function parameters. Perform multivariate logistic regression analysis to identify predictive factors for RV systolic dysfunction. A receiver operating characteristic (ROC) curve and calculate the area under the curve(AUC) to compare the diagnostic efficacy of various parameters.

Results Patients undergoing MHD exhibited varying degrees of reduced left ventricular (LV) and RV systolic function. Correlation analysis revealed that Tricuspid annular plane systolic excursion (TAPSE), Fractional area change (FAC), and Tricuspid annular peak systolic velocity(S′) were negatively correlated with LUS(r = -0.81, -0.86, -0.69), while Right ventricular free wall longitudinal strain(RVFWLS) was positively correlated with LUS (r = 0.85, P < 0.05). The ROC curve indicated that the combination of LUS and RVFWLS had the highest area under the curve (AUC = 0.963), followed by the combination of LUS and TAPSE (AUC = 0.847), LUS and FAC(AUC = 0.937), and LUS combined with S′(AUC = 0.940). All combinations demonstrated higher AUC values than the individual indicators.

Conclusions Patients with MHD combined with elevated PASP, the RV function parameters are associated with LUS, which may serve as a valuable reference indicator for assessing RV function. The use of LUS to evaluate right heart function in these patients, alongside traditional two-dimensional parameters, holds significant clinical value.

Keywords Echocardiography, Real-time three-dimensional, Speckle tracking imaging, Pulmonary hypertension, Right ventricular function

*Correspondence:
Xin Liu
lxlx3369@126.com
Full list of author information is available at the end of the article

Introduction

Pulmonary hypertension (PH) is a common complication of MHD. Studies have shown that patients undergoing MHD with PH have significantly lower survival rates than those without PH. Prolonged elevation of pulmonary arterial pressure increases the afterload on the RV, ultimately leading to RV failure, which is the main cause of death in patients with PH [1, 2].

Previous studies on MHD have mainly focused on LV function, while relatively little attention paid to RV function. Traditional two-dimensional ultrasound is difficult to accurately evaluate RV systolic dysfunction in its early stages. When RV dysfunction is diagnosed, the patient has already entered end-stage heart failure, missing the optimal treatment period. Patients undergoing MHD typically experience a prolonged state of excessive fluid overload, which is closely linked to their prognosis [3]. Lung ultrasound has high sensitivity and can detect asymptomatic pulmonary edema early, allowing for the assessment of fluid status. This article aims to analyze the significance of LUS in assessing right heart function and to explore the benefits of combining LUS with echocardiography for evaluating right heart function in patients undergoing MHD with elevated PASP.

Methods

Patient population

This retrospective study selected 85 patients who underwent regular MHD at the Hemodialysis Center at Baoding No.1 Central Hospital from January 2021 to December 2022. According to the modified Bernoulli formula, calculate the PASP, PASP = 4 × tricuspid regurgitation peak velocity^2 + right atrial pressure. The PASP of all patients was measured three times and the average value was taken. Based on the PASP, the patients were divided into three groups: the first group(40 mmHg < PASP < 50 mmHg), the second group(50 mmHg ≤ PASP ≤ 70 mmH g), and the third group(PASP > 70 mmHg). Inclusion criteria: Dialysis duration ≥ 3 months, using brachial artery to cephalic vein fistula as the access; age > 18 years old; undergoing dialysis 3 times per week with each session lasting 4 h, blood flow rate during dialysis 200–250 ml/min, dialysate flow rate 500 ml/min; willing to cooperate with various examinations, and the patient has chest CT examination data and has signed an informed consent form. Exclusion criteria: a clear history of pulmonary embolism, lung cancer, Interstitial lung disease and other pulmonary diseases; a history of other heart valve diseases except for tricuspid regurgitation, rheumatic heart disease, congenital heart disease; a history of connective tissue disease, malignant tumors, liver disease, use of immunosuppressants; idiopathic or familial PH; PH caused by pulmonary artery stenosis. kidney transplant failure requiring hemodialysis. Demographic information, such as age, gender, height, weight, heart rate, blood pressure, arterial oxygen saturation and underlying medical conditions, should be collected from patients. For dialysis patients, blood pressure and body weight should be measured before echocardiography, with blood pressure readings taken three times to determine an average. Furthermore, laboratory test results, including creatinine, hemoglobin, albumin, and electrolyte levels, should be obtained within a 3-day timeframe before the echocardiography procedure. This study was approved by the hospital's ethical committee[2023]123.

Conventional transthoracic echocardiography

In our study, the Philips EPIQ 7C system, armed with the cardiac probe S5-1、X5-1、C5-1(all operating at 1.0–5.0 MHz), was employed for ultrasound imaging. Equipped with QLAB13.0 advanced quantification software. Ultrasound assessment of dialysis patients is conducted within 2 h post-dialysis completion. The patient is positioned in a left lateral orientation, connected to an electrocardiogram, and subjected to a standard ultrasound evaluation utilizing an S5-1 probe to acquire various measurements such as right atrial diameter(RAD), right ventricular basal diameter(RVD1), right ventricular mid-cavity diameter(RVD2), main pulmonary artery diameter(PAD), interventricular septal thickness(IVS), Left ventricular posterior wall thickness(LVPW), tricuspid regurgitation velocity, calculation of FAC, determination of left ventricular ejection fraction(LVEF) using the Simpson biplane method, assessment of TAPSE via M-mode ultrasound, and evaluation of S'using tissue Doppler. Each parameter is measured thrice, and the mean value is recorded.

Real-time three-dimensional echocardiography technology and two-dimensional speckle tracking technology

During the examination, the subject should be positioned in the left lateral position. Instruct the patient to maintain calm and steady breathing. Continuously measure for four cardiac cycles at the end of expiration, and then store the images. The X5-1 probe is utilized for acquiring apical four-chamber cine images with a focus on the right ventricle. Quantitative analysis is performed using QLAB software. The 3DQ feature is used to manually adjust the endocardial border of the RV. Subsequently, the system automatically tracks and captures the surface model and relevant parameters of the RV endocardium, such as right ventricular end-diastolic volume (RVEDV), right ventricular end-systolic volume (RVESV), right ventricular stroke volume (RVSV), and right ventricular ejection fraction(RVEF). The RV Auto Strain function is employed to record the RVFWLS. Each parameter is measured three times, and the average value is computed. To standardize the measurements and adjust for variations in body size, the values of cardiac chamber volumes are normalized by the body surface area (BSA)(Fig. 1).

Pulmonary ultrasound examination

The patient is positioned in a supine or near-supine posture and instructed to breathe calmly, ensuring that both the anterior and lateral aspects of the chest wall are fully exposed. Ultrasound scanning of both thoracic cavities is performed on the anterior and lateral chest, covering the 2nd to the 5th intercostal spaces, sequentially from the parasternal line to the mid-axillary line. The lung ultrasound examination is conducted using the 8-zone method recommended by the 2012 International Conference on Lung Ultrasound [4]. Signs in each section are recorded and scored as follows: A lines or B lines ≤ 2 count as 0 points; at least one intercostal space with ≥ 3 discrete B lines counts as 1 point; fused B lines count as 2 points; and lung consolidation, fragmented signs, or pleural effusion count as 3 points. The scores from each zone are then summed to obtain a total score.

Statistical analysis

Medcalc 20.0 and SPSS Statistics 25.0 software were used for statistical analysis. A Kolmogorov–Smirnov test was used to verify the normal distribution of variables. Continuous variables were reported as mean ± standard(SD) for normally distributed variables. When comparing two groups, independent sample t-tests are commonly employed, while one-way analysis of variance is utilized for comparing multiple groups. Nonnormally distributed variables were reported as the median and interquartile range, and the chi-square test is used for comparing multiple groups. The Pearson correlation analysis method was employed to examine the relationship between LUS and right heart function parameters. An RVEF of less than 45% was classified as indicative of reduced right heart function. Multivariate logistic regression analysis was performed to identify independent risk factors associated with diminished right heart function. ROC curves were generated to assess the sensitivity and specificity of various ultrasound parameters, as well as their combinations with LUS, in diagnosing right heart dysfunction. $P < 0.05$ was deemed statistically significant.

Results

Baseline characteristics

There were no statistically significant differences in general data, including gender, age, height, weight, BSA,

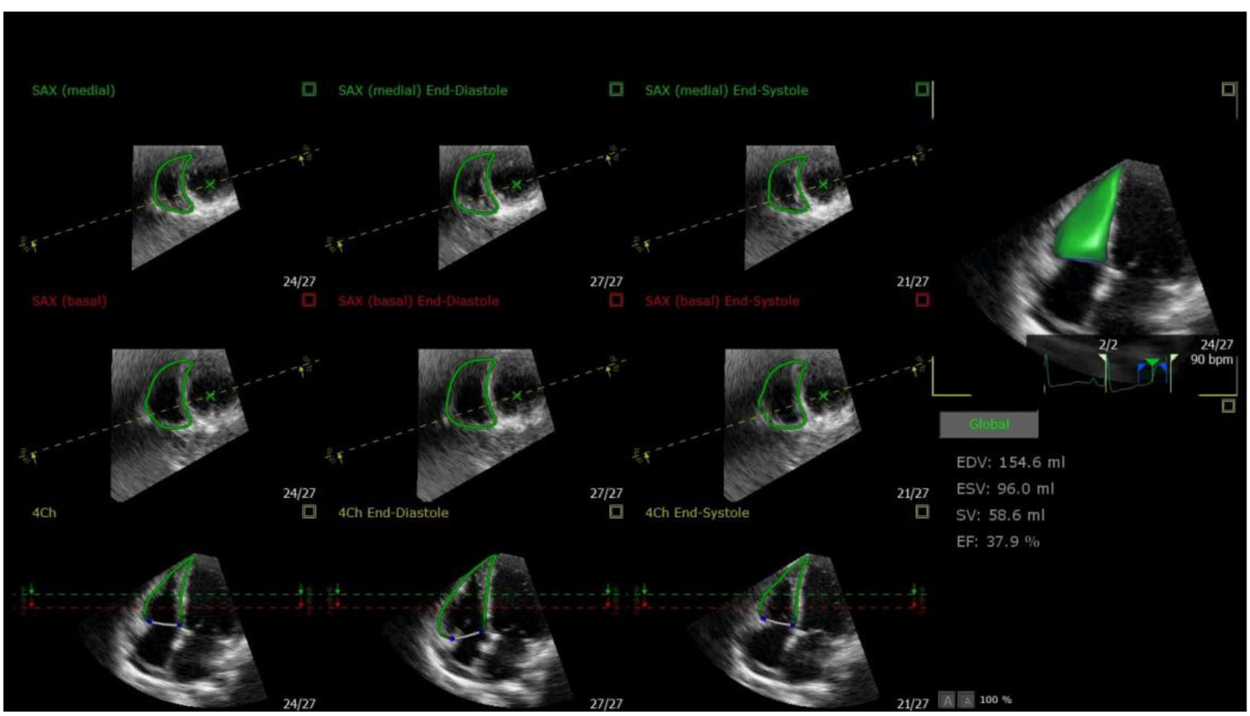

Fig. 1 Real-time three-dimensional echocardiography for measuring right ventricular volume and right ventricular ejection fraction

and dialysis duration among the groups. Compared to group 1, patients in groups 2 and 3 had elevated levels of urea and parathyroid hormone, and decreased levels of hemoglobin ($P < 0.05$). When comparing group 2 and 3, there were also elevated levels of urea and parathyroid hormone, and decreased levels of hemoglobin ($P < 0.05$). In addition, the blood oxygen saturation levels in group 3 were lower than those in groups 1 and 2 ($P < 0.05$) (Table 1).

Ultrasound parameters

A comparison of three groups based on conventional ultrasound parameters revealed that the RAD, RVD1, RVD2, PAD, LVEF, IVS, LVPW, TAPSE, FAC, and S' all demonstrated trends of change ($P < 0.05$). When examining the RV three-dimensional volume parameters among the three groups, RVEF, LUS, and RVFWLS ($P < 0.05$). The groups 2 and 3 exhibited higher RVEDV, RVESV, and LUS compared to the group 1, while RVEF and RVFWLS were lower in these groups than in the 1 group. Additionally, the group 3 had higher RVESV and LUS than the group 2, whereas RVSV, RVEF, and RVFWLS were lower in the group 3 compared to the group 2 (Fig. 2 and Table 2). LUS was negatively correlated with TAPAE, FAC, S', and RVFWLS (r = −0.81, −0.86, −0.69, −0.85, P < 0.05) (Fig. 3).

Logistic analysis

Multifactorial logistic analysis shown that LUS, RVFWLS, TAPSE, FAC, and S' are independent risk factors for diagnosing RV systolic dysfunction (Table 3). ROC curve analysis shows that RVFWLS has the highest diagnostic value for RV systolic dysfunction (AUC = 0.901), followed by S', FAC, TAPSW, and LUS. When combined with right heart function parameters, the diagnostic value of LUS combined with RVFWLS is the highest (AUC = 0.963) (Fig. 4).

Discussion

Research indicates that patients receiving MHD are at an elevated risk of developing PH. Chronic PH can lead to right heart failure, ultimately contributing to increased mortality rates among these patients [5]. The underlying mechanisms that contribute to the development of PH in individuals undergoing hemodialysis are multifaceted and complex. Notably, the survival rate for patients with

Table 1 Clinical characteristics

Variable	Group 1 (*n* = 39)	Group 2 (*n* = 28)	Group 3 (*n* = 20)	F/χ2	P
Age(years)	54.90 ± 9.26	55.04 ± 10.68	56.70 ± 9.67	0.246	0.782
Male (%)	21 (53.8)	15 (53.5)	12 (60)	0.245	0.885
height (cm)	169.41 ± 5.74	169.79 ± 5.41	170.90 ± 3.82	0.536	0.587
Weight (kg)	63.44 ± 3.47	63.39 ± 4.48	63.35 ± 3.84	0.028	0.972
BSA (m^2)	1.72 ± 0.06	1.73 ± 0.05	1.73 ± 0.04	0.672	0.513
Systolic blood pressure (mmHg)	146.49 ± 12.31	147.86 ± 14.65	150.15 ± 13.23	0.501	0.608
Diastolic blood pressure (mmHg)	92.67 ± 8.55	92.41 ± 9.58	91.80 ± 9.64	0.060	0.942
Heart rate (beats/min)	76.33 ± 4.67	76.50 ± 6.48	77.8 ± 4.53	0.545	0.582
Duration of dialysis (months)	40.56 ± 17.48	34.54 ± 15.03	35.30 ± 16.59	1.418	0.248
Urea (mmol/L)	14.67 ± 7.93	24.79 ± 10.22a	27.95 ± 13.15a	14.585	< 0.001
Blood calcium (mmol/L)	2.50 ± 0.24	2.55 ± 0.22	2.59 ± 0.21	1.079	0.325
Blood phosphorus (mmol/L)	1.72 ± 0.44	1.75 ± 0.46	1.79 ± 0.42	0.163	0.850
Hemoglobin(g/L)	101.77 ± 11.12	91.68 ± 4.85a	90.50 ± 4.43a	17.835	< 0.001
SpO2 (%)	94 (2)b	94 (2)b	93 (2)	6.586	0.037
Albumin (g/L)	44.26 ± 9.7	40.32 ± 14.38	35.4 ± 7.15[b]	4.366	0.016
Creatinine (mmol/L)	548.23 ± 235.33	600.54 ± 216.68	649.50 ± 309.91	1.145	0.323
Parathyroid hormone (pg/mL)	153.64 ± 103.29	239.04 ± 106.61	255.85 ± 100.11	8.701	< 0.001
Cause of the disease, n (%)					
Hypertensive nephropathy (%)	5 (12.82)	4 (14.28)	3 (15.00)	0.061	0.971
Diabetic nephropathy (%)	15 (38.46)	11 (39.28)	7 (35.00)	0.099	0.951
Chronic glomerulonephritis (%)	17 (43.58)	12 (42.85)	9 (45.00)	0.072	0.989
Other reasons (%)	2 (5.12)	1 (3.57)	1 (5.00)	0.100	0.951

Data are expressed as mean ± SD or as number (percentage). BSA: Surface area of the body

Compared with Group 2, a $p < 0.05$

Compared with Group 3, b $p < 0.05$

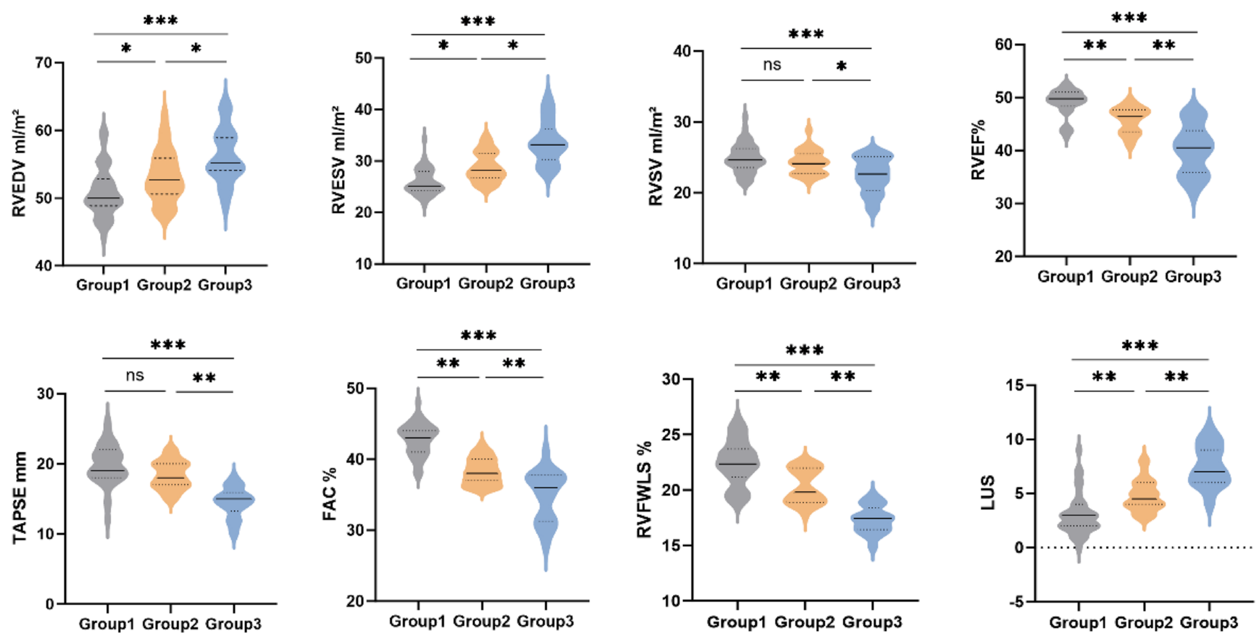

Fig. 2 The comparison of diferences in RVEDV, RVESV, RVSV, RVEF, TAPSE, FAC, RVFWLS and LUS among the groups

Table 2 Echocardiographic variable comparison between groups

Variable	Group 1 (*n* = 39)	Group 2 (*n* = 28)	Group 3 (*n* = 20)	F/χ2	P
LVEF (%)	57.21 ± 1.97	55.68 ± 1.98a	54.15 ± 2.11ab	15.854	< 0.001
IVS (mm)	10.37 ± 0.76	11.96 ± 1.13a	12.22 ± 0.88ab	36.726	< 0.001
LVPW (mm)	10.13 ± 0.58	11.38 ± 0.83a	11.43 ± 0.67ab	35.999	< 0.001
E/e'	12.27 ± 5.36	12.36 ± 4.83	13.95 ± 5.23	0.782	0.461
RAD (mm)	36.95 ± 2.29	38.75 ± 2.03a	41.20 ± 3.35ab	19.336	< 0.001
RVD1 (mm)	34.21 ± 2.35	35.93 ± 2.90a	37.85 ± 2.99ab	15.293	< 0.001
RVD2 (mm)	28.26 ± 2.34	30.11 ± 1.96a	31.95 ± 2.82ab	16.903	< 0.001
PAD (mm)	25.10 ± 2.19	27.07 ± 1.96a	28.9 ± 2.73ab	19.517	< 0.001
TAPSE (mm)	19.95 ± 2.80	19.39 ± 2.93	15.62 ± 3.09ab	15.510	< 0.001
FAC (mm)	42.05 ± 4.11	38.54 ± 3.81a	33.8 ± 4.74ab	26.138	< 0.001
S'(mm)	13.43 ± 2.52	11.22 ± 1.96a	9.62 ± 1.46ab	22.474	< 0.001
RVEDV (ml/m^2)	50.59 ± 3.63	53.33 ± 3.71a	56.25 ± 4.17a	15.115	< 0.001
RVESV (ml/m^2)	25.71 ± 2.46	28.97 ± 2.81a	34.27 ± 4.05ab	41.746	< 0.001
RVSV (ml/m^2)	24.88 ± 2.00	24.36 ± 1.65	21.97 ± 2.35ab	14.614	< 0.001
RVEF (%)	49.21 ± 2.49	45.74 ± 2.41a	39.16 ± 4.17ab	77.312	< 0.001
RVFWLS (%)	−22.67 ± 2.21	−19.60 ± 1.81a	−17.08 ± 1.19ab	54.416	< 0.001
LUS	3.51 ± 2.54	5.11 ± 2.65a	6.95 ± 1.70ab	13.649	< 0.001

Data are expressed as mean ± SD

LVEF left ventricular ejection fraction, *IVS* interventricular septal thickness, *LVPW* Left ventricular posterior wall thickness, *RAD* right atrial diameter, *RVD1* right ventricular basal diameter, *RVD2* right ventricular mid-cavity diameter, *PAD* main pulmonary artery diameter, *TAPSE* tricuspid annular plane systolic excursion, *FAC* right ventricular area change score, *S'* tricuspid annular systolic peak velocity, *RVEDV* right ventricular end-diastolic volume, *RVESV* right ventricular end-systolic volume, *RVSV* right ventricular stroke volume, *RVEF* right ventricular ejection fraction, *RVFWLS* longitudinal strain of the right ventricular free wall, *LUS* lung ultrasound score

Compared with Group 2, a $p < 0.05$

Compared with Group 3, b $p < 0.05$

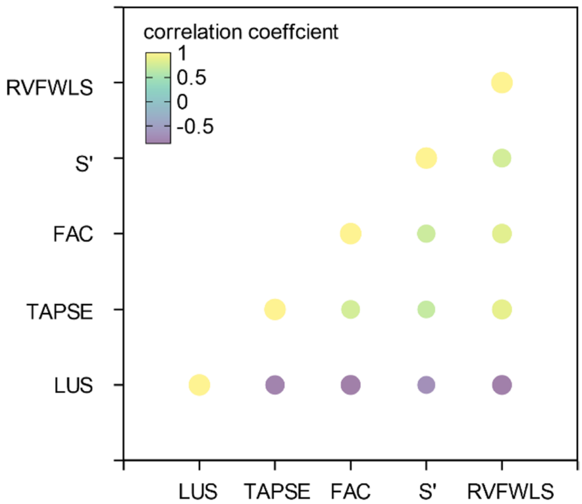

Fig. 3 The correlation analysis of LUS with TAPSE, FAC, RVFWLS, and S′

Table 3 The multifactorial analysis of right ventricular systolic dysfunction diagnosis

Variable	B	S.E	Wald	P	95% CI
TAPSE	0.67	0.32	4.47	0.03	1.97 (1.05–3.70)
FAC	0.25	0.12	3.90	0.04	1.29 (1.00–1.66)
S′	0.70	0.34	4.24	0.03	2.03 (1.03–3.98)
RVFWLS	−0.71	0.33	4.58	0.03	0.49 (0.25–0.94)
LUS	−0.70	0.30	5.49	0.01	0.49 (0.27–0.89)

PH is significantly lower compared to those without this condition. Evidence suggests that the RVEF serves as an independent predictor of mortality in patients on MHD [6]. Therefore, timely attention to the right heart function in MHD patients with elevated PASP can help improve patient survival rates. This study found that patients with MHD have elevated PASP, and there are varying degrees of right heart dysfunction among the three groups. The incidence of severe RV systolic dysfunction in the group 3 is significantly higher than in the groups 1 and 2, accompanied by more pronounced RV remodeling and dysfunction [7, 8]. Compared to traditional ultrasound, real-time three-dimensional ultrasound provides a more accurate assessment of RV volume and function.The study observed a gradual increase in RVEDV and RVESV across all three groups, accompanied by a decrease in RVEF, indicates that as the severity of PASP increases, RV volume expands, RV systolic function diminishes, and RV remodeling ensues.

The findings of this study indicate that the RVFWLS is more effective than traditional echocardiographic parameters, such as TAPSE, FAC, and S′, in assessing diminished right heart function. This observation is consistent with previous research. However, the assessment of right heart function is influenced by a greater number of factors due to the complexity of right heart structures, and the accuracy of these measurements also depends on the clinical expertise of the practitioner [9, 10]. Speckle

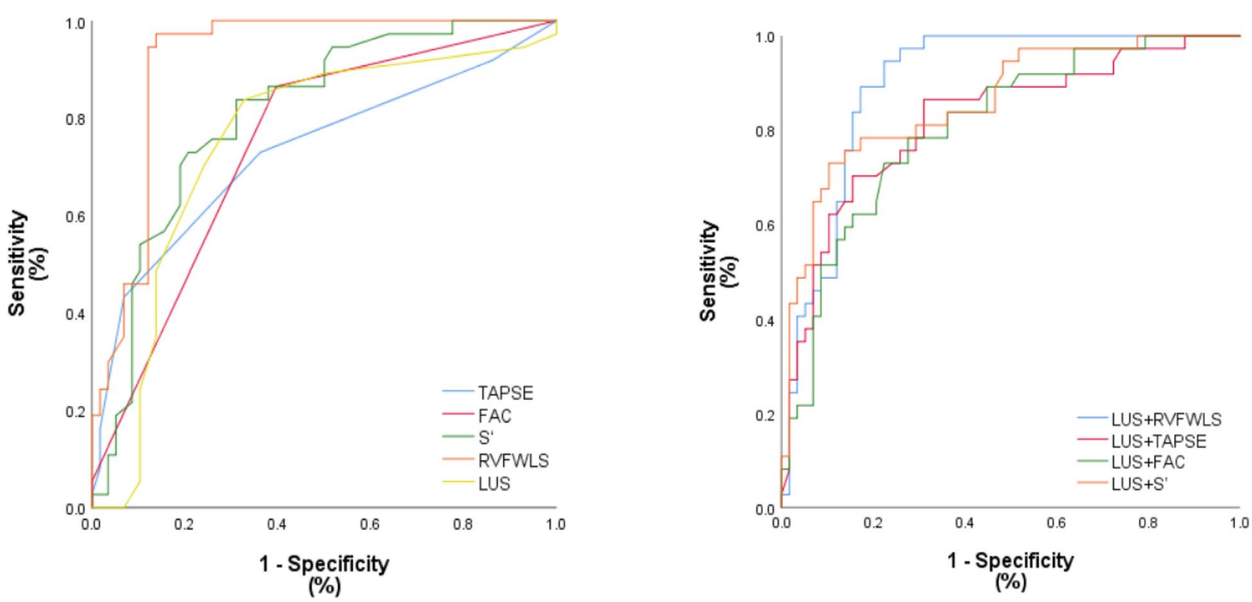

Fig. 4 The comparison of individual and combined indicators in predicting right ventricular systolic dysfunction. Individual indicator TAPSE(AUC:0.731, 95%CI:0.621–0.841), FAC(AUC:0.745, 95%CI:0.644–0.845), S′(AUC:0.809, 95%CI:0.721–0.897), RVFWLS(AUC:0.918, 95%CI:0.859–0.976), LUS(AUC:0.650, 95%CI:0.644–0.856). Composite index LUS + RVFWLS(AUC:0.910, 95%CI:0.840–0.963), LUS + TAPSE(AUC:0.822, 95%CI:0.733–0.911), LUS + FAC(AUC:0.809, 95%CI:0.721–0.897), LUS + S′ (AUC:0.862, 95%CI:0.785–0.938)

tracking technology(STI) has been extensively utilized in the assessment of cardiac function [11, 12]. In Group 2, RVFWLS shows a declining trend, falling below established normative values. The use of speckle tracking technology enables the early detection of subtle changes in myocardial architecture, thereby partially overcoming the limitations associated with conventional assessments of right heart function.

This study shows that there are differences in LVEF among the three groups of subjects, and as PASP increases, LVEF gradually decreases. In patients undergoing hemodialysis, this phenomenon is likely attributable to a combination of multiple factors. The microenvironment of hemodialysis patients is notably complex, as individuals with chronic kidney failure often present with pre-existing cardiovascular disease and associated risk factors prior to the initiation of dialysis. As the disease progresses, a reduction in LVEF is observed, and the deterioration of left heart function may further compromise right heart function.

Echocardiography is a valuable tool for evaluating cardiac function and can provide insights into the volume of extravascular lung water [13]. Lung ultrasonography serves as a straightforward diagnostic tool that can effectively indicate the extent of pulmonary edema. The accumulation of excessive fluid in the body poses a significant and potential threat to cardiovascular health, especially in individuals with advanced kidney disease [14]. Patients undergoing hemodialysis may not exhibit overt lung conditions, yet they frequently experience fluid overload [15]. This research demonstrates a positive association between LUS findings and the progression of PASP, showing significant correlations with TAPSE, FAC, S', and RVFWLS. In this study, LUS is correlated with TAPSE, FAC, S', and RVFWLS, which may pertain to a specific group of patients with PASP undergoing MHD. The causes of PH induced by MHD are complex and arise from various interrelated factors and interactions. Consequently, the reasons for pulmonary edema in hemodialysis patients are also diverse. Individuals undergoing MHD alongside PH are affected by both preload and afterload factors. Elevated preload levels can increase pulmonary venous pressure and pulmonary capillary wedge pressure, resulting in interstitial fluid accumulation, heightened extravascular lung water content, and pulmonary edema [16]. Current literature emphasizes a strong connection between LUS findings and the severity of pulmonary edema [17–19]. PH is associated with alterations in the hemodynamics of the pulmonary circulation, primarily characterized by the restructuring of pulmonary blood vessels, leading to a gradual increase in resistance over time [20]. PH results in elevated afterload on the right heart, leading to progressive structural changes in the right heart. The maintenance of pulmonary vein pressure is dependent on the pressure within the right heart, which also influences the development of pulmonary edema [21]. Consistent with the results of this study, LUS increases with the increase of PASP. Patients with MHD are prone to LV hypertrophy and LV diastolic dysfunction, which leads to an increase in LV filling pressure, resulting in an increase in LUS. In this study, almost all patients had LV diastolic dysfunction, which may contribute to the increase in LUS to some extent. At the same time, changes in volume load can also affect LUS, but in this study, patients underwent lung ultrasound examinations after hemodialysis, so the impact of volume load can be excluded.

The primary method for diagnosing PH is through right heart catheterization, although its clinical utility is constrained by its invasive nature. Studies have demonstrated a strong association between the PASP derived from the peak tricuspid regurgitation velocity assessed via ultrasound and the PASP obtained through right heart catheterization [22, 23]. In the context of predicting RV systolic dysfunction, research has shown that RVFWLS exhibits the highest prognostic value. This finding is attributed to the capability of speckle tracking technology to identify early myocardial microdamage. When integrated with other metrics, the combination of traditional right heart function parameters and LUS yielded a superior predictive capacity for RV systolic dysfunction compared to individual metrics. Notably, the predictive efficacy of RVFWLS in conjunction with LUS did not significantly differ from that of RVFWLS in isolation, although it did augment the predictive utility of LUS to some extent. The incorporation of LUS with conventional right heart function parameters has been shown to enhance diagnostic accuracy. Furthermore, considering preload maintenance in hemodialysis patients can offer valuable insights for optimizing their treatment strategies.

There are some limitations in this study: This investigation did not utilize a gold standard for diagnosing PH, which may introduce a degree of error. Research indicates that the most prevalent type is combined precapillary and post-capillary PH, followed by post-capillary PH. Additionally, the volume overload status significantly influences the types of PH observed in patients receiving hemodialysis. Consequently, this article does not specifically evaluate the various types of PH. In patients with pre-capillary PH, there may be an overestimation of the relationship between LUS and right heart function. However, the unique microenvironment of patients with both hemodialysis and PH simultaneously affects the heart and blood vessels, which may help explain the strong correlation found between LUS and right heart function in this study. Further analysis is needed on the relationship between LUS and right heart function in patients with different subtypes of PH. This study is a single-center investigation with a small sample size, which limits the generalizability of the results. Although cardiac magnetic resonance imaging was not utilized to assess right heart function, there is a strong correlation between RVEF measured by cardiac magnetic resonance and RVEF measured by real-time three-dimensional echocardiography.

Conclusions

In summary, the decline in right heart function among individuals with PH and MHD is observed as the condition advances. The LUS demonstrates a significant association with TAPSE, FAC, S', and RVFWLS. Integrating conventional right heart function metrics with LUS findings enhances the ability to predict RV systolic dysfunction. Cardiopulmonary ultrasound serves as an effective tool for evaluating right heart function in patients with hemodialysis, providing valuable insights for clinical management and prognosis assessment.

Acknowledgements
Not applicable.

Authors' contributions
Ying Xia designed the study, collected the data, and wrote the fnal manuscript. Xin Liu directed and revised the article. All authors contributed to the article and approved the submitted version.

Funding
Baoding Key Laboratory of Echocardiography supported this research.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Informed consent was obtained from all subjects and all methods were carried out in accordance with relevant guidelines and regulation. All subjects provided written informed consent prior to participation in the study. This study protocol was approved by the Ethics Committee of the Baoding No.1 Central Hospital ([2023]123).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Ultrasound, Baoding No. 1 Central Hospital, Baoding 071000, Hebei Province, China.

Received: 3 September 2024 Accepted: 6 January 2025
Published online: 20 January 2025

References

1. Thompson S, James M, Wiebe N, et al. Alberta kidney disease network. Cause of death in patients with reduced kidney function[J]. J Am Soc Nephrol. 2015;26(10):2504–11.
2. Qi YK, Cui XP, Zhang HY. The research progress on assessment methods of right heart function [J]. Chin J Tuberculosis Respir Dis. 2021;44(07):665–70.
3. Al-Saray MZ, Ali A. Lung ultrasound and caval indices to assess volume status in maintenance hemodialysis patients. POCUS J. 2023;8(1):52–9.
4. Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012;38(4):577–91.
5. Tadic M, Nita N, Schneider L, et al. The predictive value of right ventricular longitudinal strain in pulmonary hypertension, heart failure, and valvular diseases. Front Cardiovasc Med. 2021;8:698158.
6. Hickson LJ, Negrotto SM, Onuigbo M, et al. Echocardiography criteria for structural heart disease in patients with end-stage renaldisease initiating hemodialysis[J]. J Am Coll Cardiol. 2016;67(10):1173–82.
7. Harrison A, Hatton N, Ryan JJ. The right ventricle under pressure: evaluating the adaptive and maladaptive changes in the right ventricle in pulmonary arterial hypertension using echocardiography (2013 Grover Conference series)[J]. Pulm Circ. 2015;5(1):29–47.
8. Vitarelli A, Mangieri E, Terzano C, et al. Three-dimensional echocardiography and 2D–3D speckle-tracking imaging in chronic pulmonary hypertension: diagnostic accuracy in detecting hemodynamic signs of right ventricular(RV)failure[J]. J Am Heart Assoc. 2015;4(3):e1584.
9. Wang Q, Cai YX, Xu H. Application of echocardiography in evaluation of pulmonary vascular pressure and right heart function in patients with pulmonary hypertension in intensive care unit[J]. Shaanxi Med J. 2019;48(07):863–6.
10. Zeng Z, Tao S. Diagnosis value of CT pulmonary artery imaging combined with echocardiography in cardiac function damage for patients with pulmonary hypertension [J]. Chin J Modern Med. 2022;32(03):87–92. https://doi.org/10.3969/j.issn.1005-8982.
11. Tian F, Zhang L, Xie Y, et al. 3-dimensional versus 2-dimensional STE for right ventricular myocardial fibrosis in patients with end-stage heart failure[J]. JACC Cardiovasc Imaging. 2021;14(7):1309–20.
12. Abe N, Kato M, Kono M, et al. Right ventricular dimension index by cardiac magnetic resonance for prognostication in connective tissue diseases and pulmonary hypertension. Rheumatology (Oxford). 2020;59(3):622–33.
13. Aileen K, Faissal T, MarcAntoine L, et al. Volume status assessment by lung ultrasound in end-stage kidney disease: a systematic review[J]. Can J Kidney Health Dis. 2023;10:20543581231217852–20543581231217852.
14. Kuma A, Wang XH, Klein JD, et al. Inhibition of urea transporter ameliorates uremic cardiomyopathy in chronic kidney disease. FASEB J. 2020;34(6):8296–309.
15. Ng JK, Kwan BC, Chow KM, et al. Asymptomatic fluid overload predicts survival and cardiovascular event in incident Chinese peritoneal dialysis patients. PLoS ONE. 2018;13(8):e0202203.
16. Zhao Y, Qiao X. Evaluation of long-term prognosis in patients with chronic heart failure by color Doppler echocardiography combined with NT-pro BNP [J]. J Med Imaging. 2021;31(01):47–50.
17. Szymczak J, Kiełbowicz Z, Kinda W, et al. Transthoracic lung and pleura ultrasonography as a diagnostic tool of pulmonary edema in dogs and cats [J]. Pol J Vet Sci. 2018;21(3):475–81.
18. Martindale JL. Resolution of sonographic B-lines as a measure of pulmonary decongestion in acute heart failure [J]. Am J Emerg Med. 2016;34(6):1129–32.
19. Guo G, Zhang XF, Liu J, Zong HF. Lung ultrasound to quantitatively evaluate extravascular lung water content and its clinical significance [J]. Matern Fetal Neonatal Med. 2022;35(15):2904–14.
20. Li YS, Wang SS, Wang ZQ, et al. Clinical efficacy of bedside cardiopulmonary combined echocardiography in monitoring the progression of severe left heart failure with pulmonary hypertension[J]. J Xinjiang Med Univ. 2020;43(07):909–14.
21. Aschauer S, Zotter-Tufaro C, Duca F, et al. Modes of death in patients with heart failure and preserved ejection fraction. Int J Cardiol. 2017;228:422–6.
22. Palazzini M, Dardi F, Manes A, et al. Pulmonary hypertension due to left heart disease: analysis of survival according to the haemodynamic classification of the 2015 ESC/ERS guidelines and insights for future changes. Eur J Heart Fail. 2018;20(2):248–55.
23. Luo YP, Cui L, Xu L, et al. Research about the value of TTE in the assessment of risk stratification for pulmonary arterial hypertension [J]. China Med Equip. 2021;18(5):97–100.

Publisher's Note