นิพนธ์ต้นฉบับ . Original Article

พารามิเตอร์ทางคลื่นเสียงสะท้อนหัวใจในผู้ป่วยโรคไตวายเรื้อรังระยะสุดท้ายที่ได้รับการบำบัดทดแทนไต

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Echocardiographic Assessment for Early Detection of Cardiac Abnormalities in Patients with End-Stage Renal Disease Undergoing Renal Replacement Therapy

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บทคัดย่อ

หลักการและวัตถุประสงค์: โรคหัวใจและหลอดเลือดพบได้บ่อยในผู้ป่วยโรคไตวายเรื้อรังระยะสุดท้ายที่ได้รับการบำบัดทดแทนไต การตรวจพบความผิดปกติของหัวใจในระยะเริ่มต้นช่วยให้สามารถให้การรักษาได้อย่างทันท่วงทีและอาจปรับปรุงผลลัพธ์ทางคลินิก

วิธีการศึกษา: การศึกษาเชิงพรรณนาแบบตัดขวางนี้ได้วิเคราะห์ข้อมูลคลื่นเสียงสะท้อนหัวใจจากผู้ป่วยโรคไตวายเรื้อรังในหน่วยไตเทียม ช่วงวันที่ 15 มีนาคม 2563 ถึง 31 ธันวาคม 2564 โดยมีผู้ป่วยเข้าร่วมการศึกษาทั้งหมด 66 ราย มีการประเมินพารามิเตอร์ทางคลื่นเสียงสะท้อนหัวใจแบบสองมิติ เพื่อประเมินโครงสร้างและหน้าที่การทำงานของหัวใจ

ผลการศึกษา: ผู้ป่วยมีอายุเฉลี่ย 63.5 ปี (57.3–72 ปี) ในจำนวนผู้ป่วย 66 ราย เป็นเพศชาย 36 ราย (ร้อยละ 54.5) และเพศหญิง 30 ราย (ร้อยละ 45.5) พบภาวะความดันโลหิตสูงในผู้ป่วยร้อยละ 83.3 และพบภาวะเบาหวานร้อยละ 43.9 ของผู้ป่วย ตรวจพบภาวะหัวใจห้องล่างซ้ายขยายขนาดร้อยละ 7.6 ของผู้ป่วย ภาวะหัวใจห้องล่างซ้ายบีบตัวผิดปกติร้อยละ 16.7 และภาวะหัวใจห้องล่างซ้ายหนาตัวผิดปกติร้อยละ 54.5 นอกจากนี้ ยังตรวจพบภาวะหัวใจห้องล่างซ้ายคลายตัวผิดปกติ 44 ราย (ร้อยละ 66.7) และพบโรคลิ้นหัวใจผิดปกติใน 20 ราย (ร้อยละ 30.3)

สรุป: การตรวจคลื่นเสียงสะท้อนหัวใจมีบทบาทสำคัญในการวินิจฉัยความผิดปกติของหัวใจในผู้ป่วยโรคไตวายเรื้อรังระยะสุดท้าย อุบัติการณ์ที่สูงของภาวะหัวใจห้องล่างซ้ายหนาตัวผิดปกติ และภาวะหัวใจห้องล่างซ้ายคลายตัวผิดปกติ ตอกย้ำถึงความจำเป็นในการประเมินหัวใจอย่างสม่ำเสมอในกลุ่มประชากรนี้ การวิจัยในอนาคตควรเน้นการติดตามผลระยะยาว เพื่อทำความเข้าใจความเปลี่ยนแปลงของความผิดปกติของโครงสร้าง การทำงานของหัวใจและผลกระทบต่อผลลัพธ์ของผู้ป่วยให้ดียิ่งขึ้น

คำสำคัญ: โรคไตวายเรื้อรังระยะสุดท้าย, การตรวจคลื่นเสียงสะท้อนหัวใจ, การบำบัดทดแทนไต

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Abstract

Backgrounds and Objective: Cardiovascular disease is highly prevalent among patients with end-stage renal disease (ESRD) undergoing long-term renal replacement therapy (RRT). Early detection of abnormal cardiac structure may facilitate timely intervention and improve clinical outcomes.

Methods: This cross-sectional descriptive study analyzed echocardiographic data from 66 ESRD patients in a hemodialysis unit between March 15th, 2020, and December 31th, 2021. A total of 66 patients were included. Two-dimensional echocardiographic parameters were assessed to evaluate cardiac structure and function.

Results: The mean age of the patients was 63.5 years (57.3–72). Among the 66 patients, 36 (54.5%) were male, and 30 (45.5%) were female. Hypertension was present in 83.3% of patients, while 43.9% had diabetes. Left ventricular (LV) dilation was diagnosed in 7.6% of patients, LV systolic dysfunction in 16.7%, and LV hypertrophy (LVH) in 54.5%. Diastolic dysfunction was detected in 44 patients (66.7%) and valvular heart disease was observed in 20 patients (30.3%).

Conclusions: Echocardiography plays a crucial role in identifying cardiac abnormalities in patients with ESRD. The high prevalence of LVH and diastolic dysfunction underscores the need for routine cardiac evaluation in this population. Future research should focus on long-term follow-up to better understand the progression of cardiac dysfunction and its impact on patient outcomes.

Keywords: end-stage renal disease, echocardiography, renal replacement therapy

Introduction

Cardiovascular disease is common among patients with end-stage renal disease (ESRD) undergoing renal replacement therapy (RRT), with a 10- to 20-fold higher mortality rate compared to the general population[1]. According to the United States Renal Data System (USRDS), cardiovascular death accounts for 38% of all deaths, with sudden cardiac death comprising 24.3%[2]. The prevalence of cardiovascular disease in ESRD patients has been reported to be as high as 80%, as observed in the HEMO study, which identified ischemic heart disease in 39%, congestive heart failure (CHF) in 40%, arrhythmias in 31%, and other heart diseases in 61% of patients[3].

Harnett et al. reported a high prevalence of CHF (31%) at the initiation of hemodialysis, with 56% of these patients experiencing recurrent CHF during a 41-month follow-up. During dialysis, 25% of patients without pre-existing CHF developed de novo CHF[4] The average life expectancy of ESRD patients with CHF was 36 months after initiating renal replacement therapy, compared to 62 months in those without CHF[4]. Furthermore, a decline in left ventricular systolic function has been strongly associated with an increased risk of cardiovascular events and mortality[5,6].

Improvement in left ventricular abnormalities in dialysis patients was correlated with a reduction in cardiovascular events[5]. Thus, assessing echocardiographic in patients with ESRD is crucial, as the early identification of abnormal cardiac structures can facilitate timely intervention and lead to improved clinical outcomes.

In Thailand, data on the prevalence of echocardiographic abnormalities in patients with ESRD are limited, particularly within the context of community hospitals. Therefore, the objective of this study was to assess the prevalence and characteristics of echocardiographic abnormalities in ESRD patients receiving RRT at a community hospital.

Materials and Methods

This cross-sectional descriptive study included patients with ESRD who were 18 years or older, receiving maintenance hemodialysis at Borabue Hospital from March 15th, 2020 until December 31st, 2021. Patients were excluded from the study if their medical records were incomplete or unavailable for data collection. Exclusion applied to patients with hemodynamic instability, who were not referred for the echocardiogram and thus were excluded during initial screening.

Baseline laboratory tests, including a complete blood count, renal function parameters, and lipid profile, were performed as part of the routine investigation protocol. To assess cardiac structural and functional parameters, a cardiologist conducted two-dimensional echocardiography on all patients. The echocardiogram procedure was performed by the first author, Yutthapong Temtanakitpaisan, MD, a fully trained cardiologist who completed both a cardiology fellowship and an advanced echocardiography fellowship. He has been performing echocardiograms for seven years since completing his training, maintaining an annual volume exceeding 2,000 cases. The imaging was specifically conducted during the interdialytic period on a non-dialysis day using a standard echocardiographic machine.

Echocardiographic Protocol

The patient was positioned descriptive in the left lateral decubitus position following removal of clothing and application of ECG electrodes for heart rhythm recording (ECG gating). A cardiologist utilized a phased array transducer with ultrasound gel to systematically acquire standard two-dimensional (2D) images and Doppler measurements. Standard imaging windows included the parasternal, apical (two-chamber, four-chamber, three-chamber/long-axis, and five-chamber views), and subcostal views, with specific focus on the inferior vena cava (IVC) for right atrial pressure estimation. Functional assessment included color doppler for flow detection and pulsed

wave (PW), continuous wave (CW), and tissue Doppler imaging (TDI) measurements to evaluate valvular velocities, estimate pulmonary artery pressure, and assess ventricular diastolic function.

Left ventricular (LV) dysfunction was defined as an ejection fraction (EF) of less than 50%. Diastolic dysfunction was diagnosed based on the 2016 guideline of the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI), which recommend assessing four key echocardiographic parameters: mitral inflow E/A ratio, mitral annular velocity (E/e'), left atrial volume index (LAVI), and tricuspid regurgitation (TR) velocity. Diastolic dysfunction is present if at least two of these criteria are abnormal[7]. For patients with reduced LVEF, diastolic function was assessed based on E/A ratio, average E/e' ratio, TR velocity, and LAVI, following the ASE/EACVI algorithm.

LV hypertrophy (LVH) was diagnosed in patients with an interventricular septal thickness or LV posterior wall thickness of 12 mm or more. LVH geometric patterns were categorized based on the guidelines of the American Society of Echocardiography and the European Association of Cardiovascular Imaging[8].

Statistical analysis

All statistical analyses were performed using Stata version 10.1 (StataCorp, College Station, TX, USA). A p-value of less than 0.05 was considered statistically significant for all tests.

Descriptive statistics were used to summarize patient characteristics. Continuous variables were assessed for normality using the Shapiro-Wilk test. Normally distributed data are presented as mean ± standard deviation (SD), while non-normally distributed data are presented as median with interquartile range (IQR). Categorical variables are reported as frequencies and percentages (n, %).

For inferential analysis, the choice of statistical test was guided by the data distribution. To compare continuous variables between two independent groups, the independent samples Student's t-test was used for normally distributed data, and the Mann-Whitney U test was used for non-normally distributed data. For comparisons of categorical variables between two groups, the Chi-square test was employed. In cases where the expected cell count was less than five, Fisher's exact test was used instead to ensure accuracy.

Ethical approval

This study was approved with a waiver of informed consent by the Mahasarakham University Ethics Committee on November 22nd, 2022 (approval number 403-294/2022).

Results

Out of 66 patients, 36 (54.5%) were male, and 30 (45.5%) were female, with a mean age of 63.5 years IQR 57.3–72.0). The median body mass index (BMI) was 20.6 kg/m² (IQR 18.8–22.4), with 9.1% were obese (BMI ≥ 25.0), 10.6% overweight (BMI 23.0–24.9), 42.4% had normal BMI (18.5–22.9), and 22.7% were underweight (BMI < 18.5). Most patients were nonsmokers (84.8%), with 15.2% being former smokers and none currently smoking.

The most common causes of ESRD were diabetes mellitus (40.9%) and hypertension (21.2%). The prevalence of comorbid conditions was high, with 83.3% of patients having hypertension, 43.9% diabetes mellitus, 51.5% dyslipidemia, 7.6% coronary artery disease, 7.6% atrial fibrillation, and 3.0% congestive heart failure.

Regarding medication use, 31.8% of patients were on aspirin, 7.6% on clopidogrel, 33.3% on beta-blockers, 4.5% on ACE inhibitors, 7.6% on ARBs, and 48.5% on statins. The majority of patients (74.2%) underwent hemodialysis three times per week, while the remainder received dialysis twice weekly.

Electrocardiographic findings showed atrial fibrillation in 7.6% of patients. The median QRS width was 96.0 msec (IQR 84–108), and the median corrected QT interval (QTc) was 444.0 msec (IQR 393–495). During the study period, there was one reported death (1.5%) (Table 1).

Table 1 Patients' demographic and clinical characteristics (N=66)

Variables	N (%)
1. Sex	
Male	36 (54.5)
Female	30 (45.5)
2. Age	63.5 (57.3-72.0)
3. Median BMI (IQR), kg/m^2	20.6 (18.8-22.4)
Obesity (BMI ≥ 25.0)	6 (9.1)
Overweight (BMI 23-24.9)	7 (10.6)
Normal (BMI 18.5-22.9)	28 (42.4)
Thinness (BMI < 18.5)	15 (22.7)
4. Systolic blood pressure (mean±SD)	**140±12.5**
5. Diastolic blood pressure (mean±SD)	**80±6.0**
6. Smoking status	
Nonsmoker	56 (84.8)
Ex-smoker	10 (15.2)
Smoker	0 (0.0)
7. Cause of ESRD	
Hypertension	14 (21.2)
Diabetes mellitus	27 (40.9)
Other	10 (15.2)
Unknown	15 (22.7)
8. Underlying disease	
Hypertension	55 (83.3)
Diabetes mellitus	29 (43.9)
Dyslipidemia	34 (51.5)
Coronary artery disease	5 (7.6)
Atrial fibrillation	5 (7.6)
Congestive heart failure	2 (3.0)
7. Medication use	
Aspirin	21 (31.8)
Clopidogrel	5 (7.6)
Beta-blocker	22 (33.3)
ACEI	3 (4.5)
ARB	5 (7.6)
Statin	32 (48.5)
8. Dialysis frequency	
2 times a week	17 (25.8)
3 times a week	49 (74.2)

Table 1 Patients' demographic and clinical characteristics (N=66) (Cont.)

Variables	N (%)
9. Laboratory data, median (IQR)	
Hemoglobin (g/dL)	9.6 (8.1-11.1)
Blood urea nitrogen (mg/dL)	58.3 (37.7-75.6)
Creatinine (mg/dL)	10.8 (8.9-13.4)
Albumin (g/dL)	3.8 (3.4-4.2)
Cholesterol (mg/dL)	147.0 (132.5-184.5)
Triglyceride (mg/dL)	108.0 (87.5-148.0)
HDL (mg/dL)	45 (41.0-52.5)
LDL (mg/dL)	78.0 (65.5-103.5)
Sodium (mmol/L)	132.0 (127.8-136.2)
Potassium (mmol/L)	4.2 (3.6-4.8)
Chloride (mmol/L)	94.6 (89.3-99.9)
Bicarbonate (mmol/L)	24.4 (20.6-28.2)
Calcium (mg/dL)	8.8 (8.0-9.6)
Phosphate (mg/dL)	3.5 (2.4-4.4)
10. EKG	
Atrial fibrillation	5 (7.6)
QRS width (msec), median (IQR)	96.0 (84-108)
QTc (msec), median (IQR)	444.0 (393-495)
19. Death	1 (1.5)

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body mass index; EKG, electrocardiogram; ESRD, end-stage renal disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein; QTc, corrected QT interval.

Echocardiographic assessment revealed that LVH was present in 36 patients (54.5%), with concentric hypertrophy in 26 (39.4%) and eccentric hypertrophy in 10 (15.2%). Left ventricular dilation was noted in 5 patients (7.6%). Left ventricular systolic dysfunction was present in 11 patients (16.7%) and was classified as mild in 6 patients (9.1%; LVEF 40–49%), moderate in 2 patients (3.0%; LVEF 30–39%), and severe in 3 patients (4.5%; LVEF <30%).

Diastolic dysfunction was the most common abnormality, detected in 44 patients (66.7%). Right ventricular dysfunction was found in 5 patients (7.6%). Left atrial enlargement was identified in 16 patients (24.2%), and valvular heart disease was observed in 20 patients (30.3%). Pulmonary hypertension was present in 3 patients (4.5%). Additionally, pericardial effusion was noted in 9 patients (13.6%) (table 2).

Table 2 Echocardiographic findings (N=66)

Variables	N (%)
Left ventricular hypertrophy	36 (54.5)
Concentric hypertrophy	26 (39.4)
Eccentric hypertrophy	10 (15.2)
Left ventricular dilation	5 (7.6)
Left ventricular systolic dysfunction (LVEF <50%)	11 (16.7)
Mild dysfunction (LVEF 40-49%)	6 (9.1)
Moderate dysfunction (LVEF 30-39%)	2 (3.0)
Severe dysfunction (LVEF <30%)	3 (4.5)
Diastolic dysfunction	44 (66.7)
Right ventricular dysfunction	5 (7.6)
Left atrial enlargement	16 (24.2)
Valvular disease	20 (30.3)
Pulmonary hypertension	3 (4.5)
Pericardial effusion	9 (13.6)

Abbreviation: LVEF, left ventricular ejection fraction.

Discussion

In this study, we evaluated the echocardiographic findings in patients with ESRD undergoing hemodialysis. The high prevalence of cardiac abnormalities, particularly LVH, is consistent with previous studies demonstrating that cardiovascular complications are the leading cause of morbidity and mortality in this population. The previous study[9] demonstrated a prevalence of LVH at 55%, which is quite similar to the 54.5% found in our current study. The presence of cardiac abnormalities in ESRD patients receiving RRT highlights the need for routine echocardiographic surveillance. Early detection of these abnormalities can help guide treatment strategies, including optimizing fluid management, controlling hypertension, and managing anemia. Moreover, the presence of echocardiographic abnormalities is associated with poorer cardiovascular outcomes, emphasizing the importance of a multidisciplinary approach to the care of ESRD patients. However, there are currently no official guidelines for routine echocardiographic evaluation in patients with chronic kidney disease (CKD).

By promoting a shift from reactive to proactive care, our research can guide clinical interventions. For example, identifying LVH early may prompt a more aggressive approach to blood pressure control and the use of medications proven to cause LVH regression. Furthermore, the degree of LVH and diastolic dysfunction can help clinicians optimize a patient's "dry weight" during hemodialysis, thereby reducing the strain on the heart caused by fluid overload.

Left Ventricular Remodeling and Dysfunction

The high incidence of LVH in our cohort reflects the chronic hemodynamic stress associated with ESRD, driven by both cyclic volume overload and arterial hypertension which lead to eccentric and concentric LVH, respectively. The development of

LVH is a critical prognostic factor, strongly linked to increased risk of cardiovascular events and mortality, as demonstrated in earlier studies[10].

We observed a significant prevalence of diastolic dysfunction (66.7%), which often co-exists with LVH and volume status changes. While hydration status complicates diastolic assessment, the E/e′ ratio remains a reliable parameter, and its elevation in hemodialyzed patients is known to be a strong predictor of adverse outcomes[11]. This highlights the necessity of rigorously monitoring diastolic function in routine follow-up.

In an exploratory analysis prompted by clinical relevance, we investigated whether dialysis frequency (e.g., twice versus three times per week) was associated with a higher prevalence of cardiac abnormalities such as LVH or diastolic dysfunction. However, no statistically significant associations were found within our cohort. This lack of association might be attributable to the relatively small sample size, which may have been underpowered to detect subtle differences. Alternatively, it could suggest that within this more advanced ESRD population, the cumulative burden of uremia, hypertension, and other comorbidities overwhelms the incremental effect of dialysis frequency. Future larger-scale, multicenter studies may be better positioned to identify specific predictors that could guide a more selective approach to echocardiographic screening.

Other Cardiac and Vascular Pathologies

Our findings on left atrial dilation (24.2%) and valvular disease (30.3%) are typical of a chronic volume-overloaded state, further complicated by the hyperkinetic circulation resulting from arteriovenous (AV) access and chronic anemia. The presence of these markers is associated with poor prognosis[12].

Furthermore, the prevalence of right ventricular dysfunction (7.6%) and pulmonary hypertension (4.5%) in our study, while lower than LV abnormalities, underscores the multi-system impact of uremia and high AV access flow, both of which contribute to elevated mortality risk[13,14]

Clinical Implications and Multidisciplinary Care

The documented impact of hemodialysis itself—including volume shifts and AV access flow volume—on various echocardiographic parameters necessitates that studies are performed under standardized conditions (e.g., at least 24 hours post-dialysis) to ensure accurate baseline assessment[15–17]

Ultimately, our data emphasize the need for a more unified, multidisciplinary approach between nephrologists and cardiologists. Given the strong prognostic implications of these structural heart changes, a lack of coordinated management often leads to suboptimal care. Integrating systematic echocardiographic evaluation into the standard ESRD care pathway is crucial for optimizing cardiovascular outcomes.

Cardiovascular disease remains the leading cause of death in long-term dialysis patients, yet data guiding the treatment of CHF in this specific cohort are notably limited[18]. Evidence consistently suggests that guideline-recommended CHF medications are often underutilized in this population. For instance, Trespalacios et al. reported that the combined use of beta-blockers and renin-angiotensin-aldosterone system (RAAS) inhibitors was below 25% among long-term hemodialysis patients[18].

Our study reflects this ongoing clinical dilemma. We observed beta-blocker use at 33.3%, while the utilization of RAAS inhibitors was very low (ACEI use at 4.5% and ARB use at 7.6%).

This low adoption of RAAS inhibitors, despite their well-documented cardiovascular benefits, is likely driven by the common and valid clinical concern regarding hyperkalemia in dialysis patients. While RAAS inhibitors provide crucial benefits—such as preventing cardiovascular remodeling and mitigating heart failure progression—concerns over life-threatening electrolyte disturbances often lead to therapeutic caution[19]. This cautious approach, while necessary, highlights a clinical dilemma: balancing the risks of hyperkalemia against the benefits of reduced cardiovascular mortality results in the underutilization

of potentially life-saving neurohormonal modulation therapy in our cohort. Careful, individualized treatment and close electrolyte monitoring are therefore essential to optimize outcomes.

Beyond pharmacotherapy, the clinical management challenge is compounded by the difficulty of differentiating between volume overload and heart failure exacerbation in these patients, often leading to a greater reliance on ultrafiltration over optimizing neurohormonal strategies. Furthermore, repetitive episodes of myocardial ischemia induced by the dialysis process itself may also contribute to the progression of myocardial dysfunction[20].

We recommend the systematic integration of echocardiography into the routine follow-up protocol for ESRD patients, even in community hospitals. This proactive screening facilitates the early detection of structural heart changes, such as LVH, allowing for timely intervention and improved long-term cardiovascular outcomes in this high-risk patient cohort.

Limitations: This study has several limitations. First, as a single-center study, its findings may not be generalizable to all dialysis populations, as patient characteristics, treatment protocols, and facility resources may vary across different centers. Additionally, selection bias may be present, as the study population might not fully represent the broader ESRD population on dialysis.

Second, the retrospective study design limits the ability to establish causal relationships between dialysis and changes in echocardiographic parameters. While associations were identified, further prospective studies are needed to confirm the causal impact of volume management on cardiac structural changes.

Lastly, the study did not account for potential confounding factors, such as medication use and comorbid conditions, which may influence cardiac parameters. Future research should incorporate these variables to provide a more comprehensive analysis in a prospective fashion.

Conclusions

This study confirms the significant cardiovascular burden carried by patients with ESRD undergoing RRT, specifically highlighting the high prevalence of LVH, LV systolic dysfunction, and diastolic dysfunction. Based on these findings, we strongly encourage the proactive application of guideline-directed medical therapy for these conditions.

To effectively manage this high cardiovascular risk, routine echocardiography assessment is essential and should be considered annually in this patient population. Echocardiographic parameters offer critical insights into cardiac function, structure, and volume status, which are all vital for effective management. This intermittent monitoring is particularly beneficial because RRT, especially hemodialysis, significantly influences cardiac parameters by acutely altering hemodynamic load and blood volume, thus contributing to the observed structural cardiac changes.

Declarations

- Ethics approval and consent to participate: This study was approved by the Mahasarakham University Ethics Committee on November 22nd, 2022 (approval number 403-294/2022).
- Consent for publication: Not applicable.
- Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.
- Competing interests: The authors declare that they have no competing interests" in this section.
- Funding: No funding was received for this study.
- Authors' contributions:
  Yutthapong Temtanakitpaisan: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Suchaorn**

Saengnipanthkul: Conceptualization, Methodology, Formal analysis, Writing – review and editing, Visualization. **Sathita Ruengsiriphakakul:** Conceptualization, Resources, Writing – review and editing.

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