fortune Journals

Research Article

ARCHIVES OF NEPHROLOGY AND UROLOGY

ISSN: 2644-2833

Pattern and Predictors of Cardiac Rhythm Disturbances in Patients on Maintenance Hemodialysis

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Abstract

Background: Sudden cardiac death (SCD) is the major cause of death among patients on maintenance hemodialysis. It is closely associated with cardiovascular and metabolic changes occurring in patients undergoing hemodialysis. Cardiac arrhythmias were frequently observed in these dialysis patients.

Aim of the study: To detect the pattern and predictors of cardiac rhythm disturbances in maintenance hemodialysis patient.

Methods: This cross-sectional study was conducted in the Department of Nephrology at BSMMU, Dhaka. A total of 49 patients on maintenance hemodialysis were included based on selection criteria. After inclusion, ECG & echocardiogram were performed on non-dialysis day. On dialysis day, 24-hour Holter ECG monitoring, selective pre & post dialytic laboratory investigations were carried out. The sampling method used was purposive sampling. Data were collected using a predesigned data collection sheet, including patient history and clinical examination. Statistical analyses of the results were performed using software with SPSS-26.

Result: The mean age of the study cohort was 42.1 ± 12.3 years, with a predominance of male patients (73.5%). The primary etiology of renal failure was glomerulonephritis (46.9%), followed by diabetes mellitus (36.7%) and hypertension (16.3%). Echocardiographic assessment revealed a mean left ventricular mass index (LVMI) of 130.6 ± 43.7 g/m². Pulmonary artery systolic pressure (PASP) was significantly elevated in patients with tachyarrhythmia (37.7 ± 15.1 mmHg) compared to those without (29.4 ± 13.3 mmHg, $p<0.05$). Supraventricular arrhythmias were frequent, with premature atrial contractions (PACs) observed in 77.6% of patients; PAC burden averaged 2.49 ± 8.60 per hour, and 8.2% had >70 PACs/day. Ventricular arrhythmias, predominantly premature ventricular contractions (PVCs), occurred in 71.4%, with a mean rate of 0.61 ± 1.22 per hour; 5.7% exhibited a PVC burden between 5–10%. Bradyarrhythmias and tachyarrhythmias were present in 59.2% and 65.3% of patients, respectively. Logistic regression identified significant associations of PACs with post-dialysis magnesium levels, and PVCs with post-dialysis potassium, magnesium, LVMI, and PASP. No correlation was found between arrhythmias and dialysis access type or frequency.

Conclusion: Arrhythmias including significant abnormal rhythms, were common but their burden was less. Tachyarrhythmias occurred more often during and immediately after dialysis where bradyarrhythmias were less prevalent in initial period & increased with time. Further study is needed to determine their impact on clinical outcomes.

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Citation: Md. Saiful Ahammad Sarker, Asia Khanam, Md. Fakhrul Islam Khaled, S. M. Remin Rafi, Afrin Akter, Anjuman Ara Daisy, SK Afsana Hossain, H. M. Mohiuddin Alamgir, Mohammad Kamrul Hasan. Pattern and Predictors of Cardiac Rhythm Disturbances in Patients on Maintenance Hemodialysis. Archives of Nephrology and Urology. 8 (2025): 126-134.

Received: August 13, 2025
Accepted: August 25, 2025
Published: December 13, 2025

Md. Sarker SA, et al., Arch Nephrol Urol 2025
DOI:10.26502/anu.2644-2833106

Keywords: Cardiac rhythm disturbances; Maintenance hemodialysis; Chronic Kidney Disease Stage 5 (CKD-5); Arrhythmias; Holter monitoring

Introduction

Chronic Kidney Disease (CKD) is a global public health concern characterized by a progressive decline in renal function, defined by structural or functional kidney abnormalities persisting for over three months [1]. As CKD advances, it often culminates in End-Stage Renal Disease (ESRD), necessitating Renal Replacement Therapy (RRT) for patient survival [2]. Among the modalities of RRT, hemodialysis (HD) remains a cornerstone treatment, facilitating the removal of excess fluid, metabolic waste, and toxins from the bloodstream using an extracorporeal circuit [3]. Despite its life-sustaining benefits, HD is strongly associated with significant cardiovascular morbidity and mortality. Cardiovascular disease (CVD) remains the leading cause of death in ESRD patients, accounting for over 50% of all deaths according to the 2016 US Renal Data System (USRDS) report [4]. Notably, sudden cardiac death (SCD), often due to arrhythmias, contributes to nearly 37% of these fatalities. The mortality rate among patients undergoing maintenance hemodialysis (MHD) for more than three months is 10–15 times higher than that of the age- and sex-matched general population [5]. Ventricular arrhythmias are particularly prevalent and are considered a major risk factor for SCD in this population [6,7]. Studies utilizing 24-hour Holter monitoring have shown that ventricular arrhythmias affect 13% to 50% of HD patients [7]. These arrhythmias are frequently linked with structural heart disease, such as left ventricular hypertrophy (LVH), left ventricular (LV) systolic and diastolic dysfunction, and vascular calcification [8]. Moreover, atrial fibrillation (AF), another common arrhythmia in ESRD, affects 13% to 23.4% of patients on HD and is associated with a heightened risk of thromboembolic events, including stroke [9]. Cardiac arrhythmias in CKD patients arise from a complex interplay of arrhythmogenic substrates, triggering factors, and autonomic nervous system dysfunction [10]. Electrocardiography and echocardiography play pivotal roles in identifying structural abnormalities, while heart rate variability (HRV) offers insights into autonomic regulation. Reduced HRV, indicative of autonomic dysfunction, has been linked with ventricular arrhythmia and increased SCD risk in HD patients [11]. LVH, a prevalent complication in CKD, results from volume overload, hypertension, sympathetic overactivity, and renin-angiotensin system activation [12]. Non-hemodynamic contributors include anemia, mineral bone disorders, inflammation, and dysregulated calcium-phosphorus metabolism, all of which promote myocardial fibrosis and dysfunction [13]. Similarly, systolic dysfunction and reduced ejection fraction predispose patients to arrhythmias via sympathetic neurohumoral activation [14]. Pulmonary arterial hypertension (PAH), seen in up to one-third of MHD patients, also correlates with arrhythmic events in about 16% of cases [15]. Furthermore, electrolyte imbalances—such as hyperkalemia, hypocalcemia, and hyperphosphatemia—are common in ESRD and contribute to the development of fatal arrhythmias [16]. Hemodialysis procedures themselves can provoke arrhythmogenic events, particularly AF [17]. However, data on the patterns and predictors of cardiac arrhythmias in HD patients in Bangladesh remain sparse. This study aims to explore the prevalence, types, and associated factors of cardiac rhythm disturbances among MHD patients in Bangladesh, thereby contributing valuable insights for risk stratification, monitoring, and preventive strategies in this high-risk population.

Methodology and Materials

This cross-sectional observational study was conducted at the Department of Nephrology, Bangabandhu Sheikh Mujib Medical University (BSMMU), and Dhaka, Bangladesh. The study was carried out over a period of 18 months, from April 2023 to September 2024. Participants were recruited from both the inpatient and outpatient hemodialysis (HD) units under the Department of Nephrology.

Study Population

The study included adult patients (≥18 years) with end-stage renal disease (CKD Stage 5) undergoing maintenance hemodialysis (MHD) for a minimum duration of 3 months. Purposive sampling was employed. A total of 50 patients were enrolled, of which one patient was excluded due to incomplete Holter ECG data, resulting in a final analyzed cohort of 49 patients.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Age ≥ 18 years
- On maintenance hemodialysis for ≥ 3 months

Exclusion Criteria

- Structural or congenital heart disease
- Known arrhythmia or previous diagnosis of paroxysmal atrial fibrillation, WPW syndrome, Brugada syndrome, or long QT syndrome
- Ischemic heart disease or history of sudden cardiac arrest
- Thyroid dysfunction, COPD, bronchial asthma
- Use of arrhythmogenic drugs (e.g., salbutamol, theophylline, amphetamine, caffeine, alcohol)

Data Collection Procedure

After obtaining ethical approval from the Institutional Review Board (IRB) of BSMMU and informed written consent from participants, detailed demographic, clinical,

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dialysis-related, echocardiographic, and laboratory data were collected using a structured data collection form. Information included age, sex, BMI, smoking history, comorbidities (diabetes, hypertension, dyslipidemia), and current medications (e.g., β-blockers, CCBs, α-blockers). Dialysis data encompassed frequency, duration, interdialytic weight gain, and access type. All patients received standard bicarbonate dialysis using synthetic dialyzers (Fresenius 4008, dialyzer size 1.6–1.8 m², blood flow rate 200–400 mL/min, dialysate flow 500 mL/min).

Laboratory and Echocardiographic Evaluation

Venous blood samples were drawn before and after dialysis for hematologic and biochemical analysis, including hemoglobin, electrolytes, albumin, calcium, magnesium, phosphate, bicarbonate (TCO_2), and intact parathyroid hormone (iPTH). Laboratory analyses were performed in respective departments at BSMMU using standard techniques and reagents. Transthoracic echocardiography was conducted on interdialytic days using GE Vivid E9 equipment. Parameters assessed included left ventricular ejection fraction (LVEF, Teicholz method), left ventricular mass index (LVMI), left ventricular internal diameter (LVIDD), and pulmonary artery systolic pressure (PASP, Bernoulli equation).

Holter ECG Monitoring

All patients underwent continuous 24-hour Holter ECG monitoring using the DMS 300–4A recorder. Monitoring began just prior to the dialysis session and continued throughout the day and night. Patients were instructed to maintain regular activities while avoiding showers. Data were extracted and analyzed by a cardiologist blinded to clinical and laboratory information. Arrhythmia types, burden, and patterns—including PACs, PVCs, bradyarrhythmias, and tachyarrhythmias—were recorded and quantified.

Statistical Analysis

All data were entered, verified, and analyzed using IBM SPSS version 26. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using unpaired or paired t-tests as appropriate. Chi-square tests were used for categorical associations. Logistic regression analysis was used to identify independent predictors of specific arrhythmia types. A two-tailed p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted in compliance with the Declaration of Helsinki (1964) for human research ethics. Ethical approval was obtained from the Institutional Review Board of BSMMU. Informed consent was obtained in both English and Bangla from each participant. Confidentiality of data was maintained throughout, and participation was voluntary with full rights to withdraw at any time without consequences. No financial compensation was provided, and there was no conflict of interest.

Result

The study population had a mean age of 42.1 ± 12.3 years, with 53.06% over 40 and a male predominance (73.47%). The average weight was 63.0 ± 11.3 kg and BMI 23.6 ± 4.8 kg/m², with most patients having normal BMI. Hypertension was the most common comorbidity (95.92%), followed by diabetes (36.73%) and dyslipidemia (12.24%). Most patients were on DHP-CCBs (75.51%), β-blockers (67.35%), and α-blockers (32.65%). Only 4.08% reported current smoking (Table 1). The average dialysis duration was 15.6 ± 14.4 months. 79.59% underwent two hemodialysis sessions per week. The predominant vascular access was an arteriovenous fistula, used by 91.84% of patients, with only 8.16% relying on a permanent catheter. On dialysis days, the average session duration was consistently 4 hours. The mean ultrafiltration volume was 2.34 ± 0.92 liters, and the average interdialytic weight gain was 2.39 ± 0.95 kg. 82.4 ± 7.13 beats per minute was the mean pulse rate, whereas 143.7 ± 16.1 mmHg and 84.8 ± 11.1 mmHg were the mean systolic and diastolic blood pressures, respectively (Table 2). The most common cause of renal failure in the study population was glomerulonephritis (46.9%), followed by diabetes mellitus (36.7%) and hypertension (16.3%) (Figure 1). Among all hemodialysis patients, 95.92% had preserved ejection fraction (mean LVEF 60.5 ± 5.5%), while 4.08% had reduced EF. The mean LVMI was 130.6 ± 43.7 g/m² and LVIDD was 52.2 ± 5.16 mm. Diastolic dysfunction was observed in 28.57% of cases, mostly Grade 1. Aortic sclerosis was found in 8.16%, and the mean PASP was 32.3 ± 14.3 mmHg (Table 3). While sodium levels remained unchanged (137.4 mmol/L; p=1.0), significant reductions were seen in potassium (4.67 ± 0.64 to 4.16 ± 0.55 mmol/L; p<0.001), inorganic phosphate (4.51 ± 1.09 to 4.14 ± 1.07 mg/dL; p=0.014), and magnesium (non-significant). Bicarbonate (TCO_2) increased significantly post-dialysis (20.53 ± 3.39 to 25.45 ± 2.68 mmol/L; p=0.001), along with calcium (8.85 ± 1.15 to 9.28 ± 1.73 mg/dL; p=0.023) (Table 4). Holter monitoring showed a high incidence of arrhythmias, with PACs in 77.55% and PVCs in 71.43% of patients. Bradyarrhythmia was seen in 59.18%, and tachyarrhythmia in 65.31% (Table 5). Tachyarrhythmias were most frequently observed within the first 0–6 hours (38.8%). Incidences declined sharply thereafter, with 6.1% between 12–18 hours, and only 2% between 18–24 hours. No tachyarrhythmias were detected in 32.7% of patients (Figure 2). Figure 3 shows that Bradyarrhythmias were most commonly observed during 12–18 hours and 18–24 hours (each 20.4%). A smaller portion (4.1%) occurred during 0–6 hours, while 40.8% of patients exhibited no bradyarrhythmias

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Md. Sarker SA, et al., Arch Nephrol Urol 2025
DOI:10.26502/anu.2644-2833106

Table 1: Baseline demographic and clinical characteristics of the study population (N = 49).

Variable	Frequency (n)	Percentage (%)
Age group (years)		
<40	23	46.94
>40	26	53.06
Mean ± SD	42.1±12.3	
Gender		
Male	36	73.47
Female	13	26.53
Weight (kg)		
Mean ± SD	63.0±11.3	
BMI (kg/m2)		
Underweight (<18.5)	5	10.20
Normal (18.5-24.9)	31	63.27
Overweight (25-29.9)	11	22.45
Obese (>30)	2	4.08
Mean ± SD	23.6±4.8	
Current smoking	2	4.08
Comorbidities		
Diabetes mellitus	18	36.73
Hypertension	47	95.92
Dyslipidemia	6	12.24
Antihypertensive medication		
DHP-CCB	37	75.51
β-blocker	33	67.35
α-blocker	16	32.65

Table 2: Hemodialysis parameters and On-Dialysis physiological parameters in the study cohort (N = 49).

Dialysis variables	Frequency (n)	Percentage (%)
Dialysis Duration (months) (mean ±SD)	15.6 ± 14.4	
HD Sessions per Week		
2	39	79.59
3	10	20.41
HD Access Type		
Arteriovenous Fistula	45	91.84
Permanent Catheter	4	8.16
Measurement on Dialysis Day (mean ±SD)		
Dialysis Duration (hours)	4.0 ± 0.0	
Ultrafiltration (L)	2.34 ± 0.92	
Interdialytic Weight Gain (Kg)	2.39 ± 0.95	
Pulse (beats/min)	82.4 ± 7.13	
Systolic BP (mmHg)	143.7 ± 16.1	
Diastolic BP (mmHg)	84.8 ± 11.1	

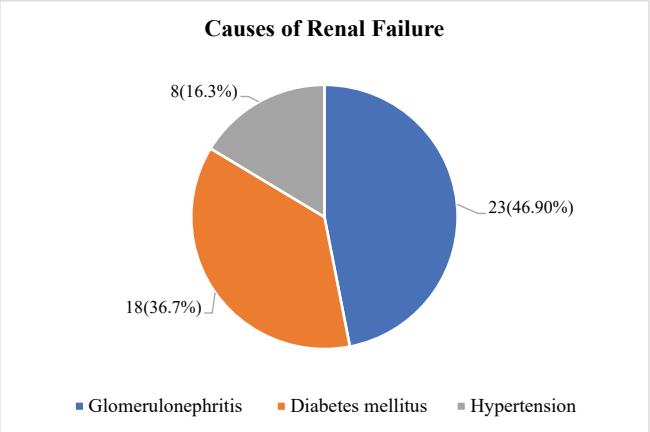

Figure 1: Distribution of the study patients by causes of renal failure (N=49)

Table 3: Comprehensive echocardiographic findings in patients receiving maintenance hemodialysis (N = 49).

Echocardiographic findings	Frequency (n)	Percentage (%)
Ejection fraction		
<50%	2	4.08
>50%	47	95.92
Mean±SD	60.5±5.5	
LVMI (g/m2)	130.6±43.7	
LVIDD (mm)	52.2±5.16	
Diastolic dysfunction		
Grade 1	8	16.33
Grade 2	3	6.12
Grade 3	1	2.04
Aortic sclerosis	4	8.16
PASP (mmHg)	32.3±14.3	

Table 4: Pre- and post-dialysis laboratory measurements and biochemical changes (N=49).

Parameter	Before Dialysis	After Dialysis	p-value
Hemoglobin (g/dL)	10.0 ± 1.23	-	-
Sodium (mmol/L)	137.4 ± 3.65	137.4 ± 3.28	1
Potassium (mmol/L)	4.67 ± 0.64	4.16 ± 0.55	<0.001*
TCO_2 (mmol/L)	20.53 ± 3.39	25.45 ± 2.68	0.001*
Calcium (mg/dL)	8.85 ± 1.15	9.28 ± 1.73	0.023*
Magnesium (mg/dL)	2.55 ± 2.77	2.25 ± 0.54	0.49
Inorganic Phosphate (mg/dL)	4.51 ± 1.09	4.14 ± 1.07	0.014*
Albumin (g/L)	35.8 ± 6.01	35.60 ± 6.19	0.798
PTH (pg/mL)	294.6 ± 212.8	-	-

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Table 5: Distribution and characteristics of arrhythmias detected by 24-hour Holter monitoring.

Variable	Frequency (n)	Percentage (%)
Holter Monitoring Parameters (Mean ± SD)		
Duration of recording (hours)	22.9 ± 2.01	
Mean heart rate (beats/min)	78.1 ± 11.21	
Supraventricular Arrhythmias		
Patients with PACs	38	77.55
PACs (total count)	58.8 ± 167.0	
PACs per hour	2.49 ± 8.60	
PACs <70 per day	34	89.47
PACs >70 per day	4	10.53
Ventricular Arrhythmias		
Patients with PVCs	35	71.43
PVCs (total count)	18.6 ± 27.4	
PVCs per hour	0.61 ± 1.22	
PVCs <5% of total beats	33	94.29
PVCs 5-10% of total beats	2	5.71
Bradyarrhythmias		
Patients with sinus bradycardia (<60 bpm)	29	59.18
Tachyarrhythmias		
Patients with tachyarrhythmia (>100 bpm)	32	65.31

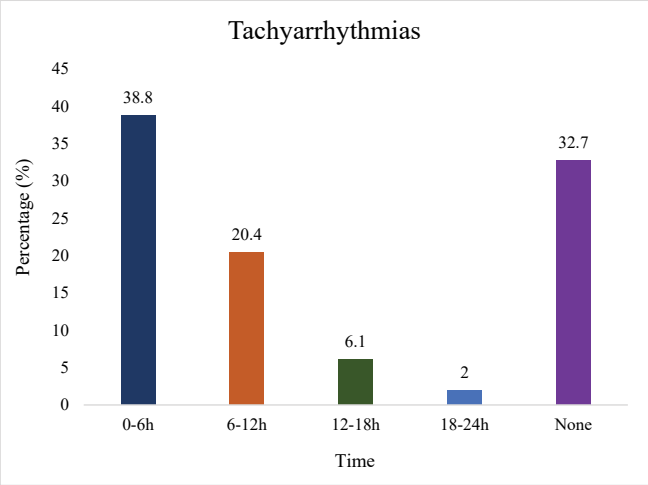

Figure 2: Tachyarrhythmias in different time

during the monitoring period. Logistic regression analysis revealed that lower post-dialysis magnesium levels were significantly associated with premature atrial contractions (PACs) (p=0.004). Low post-dialysis potassium (p=0.033) and magnesium (p=0.039), along with higher LVMI (p=0.008) and PASP (p=0.026), were significant predictors of premature ventricular contractions (PVCs). Diabetes mellitus showed a protective effect against bradyarrhythmia (p=0.028), and higher PASP was significantly associated with tachyarrhythmia (p=0.042) (Table 6). Comparison between patients with and without tachyarrhythmia showed that those with arrhythmia had significantly higher PASP (37.7 ± 15.1 vs. 29.4 ± 13.3 mmHg; *p*=0.042) and lower ejection fraction (59.3 ± 5.4% vs. 62.6 ± 5.2%; *p*=0.044). No significant differences were observed in demographic, comorbidity, or dialysis access and frequency variables (Table 7). B-blocker use was significantly associated with a lower overall arrhythmia rate (*p*=0.018) and specifically with fewer PVCs (*p*=0.021), though no significant associations were found with PACs, tachyarrhythmia, or bradycardia (Table 8).

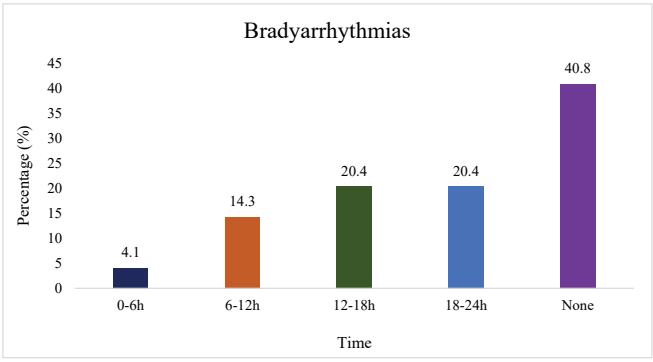

Figure 3: Bradyarrhythmias in different time.

Discussion

Cardiac rhythm disturbances are a major cause of morbidity and mortality among patients with end-stage renal disease (ESRD) undergoing maintenance hemodialysis (MHD). These disturbances are driven by complex interactions among electrolyte imbalances, fluid overload, uremic toxins, and cardiac structural abnormalities. As these arrhythmias often remain asymptomatic, early identification and assessment of predictive factors are crucial for improving outcomes in this vulnerable population [18]. This study evaluated 49 patients on MHD and found a mean age of 42.1±12.3 years, with 53.06% being older than 40. This aligns with evidence suggesting that advancing age is linked to increased cardiovascular risk due to prolonged exposure to hypertension, diabetes, and uremia [19]. A male predominance (73.47%) was observed, in line with global trends indicating a higher burden of CKD progression in males [20]. Most patients had a normal BMI (mean 23.6±4.8 kg/m²), but 10.2% were underweight and 26.5% were overweight or obese. Although BMI was within acceptable limits for the majority, CKD-related metabolic alterations may still predispose patients to arrhythmias [21]. Only 4.08% of patients were current smokers, which may reflect sociocultural factors or successful public health interventions in Bangladesh [22]. Hypertension was the most prevalent comorbidity (95.92%), underscoring its etiological and pathophysiological role in CKD and its complications [23]. Diabetes mellitus was present in 36.73% of patients, while dyslipidemia was noted in 12.24%, possibly reflecting local dietary habits [24]. Antihypertensive usage was high,

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Table 6: Logistic regression analysis of predictors of premature atrial and ventricular contractions, bradycardia, and tachyarrhythmia.

Arrhythmia Type	Predictor Variable	OR (95% CI)	p-value
PACs	Age > 40 years	0.416 (0.104–14.66)	0.208
	Diabetes Mellitus	3.27 (0.62–17.20)	0.147
	Hypertension	3.70 (0.212–64.50)	0.34
	Potassium (post-dialysis)	0.150 (0.01–2.11)	0.159
	Calcium (post-dialysis)	0.854 (0.41–1.76)	0.671
	Magnesium (post-dialysis)	0.000 (0.000–0.031)	0.004*
	Bicarbonate (TCO_2)	0.869 (0.62–1.22)	0.423
	Ejection Fraction (%)	1.03 (0.89–1.17)	0.712
	LVMI (g/m²)	0.989 (0.97–1.01)	0.269
	PASP (mmHg)	0.992 (0.94–1.05)	0.784
PVCs	Age > 40 years	0.370 (0.102–1.34)	0.124
	Diabetes Mellitus	1.67 (0.44–6.38)	0.453
	Hypertension	2.62 (0.15–44.90)	0.493
	Potassium (post-dialysis)	0.110 (0.01–0.84)	0.033*
	Calcium (post-dialysis)	0.498 (0.25–1.00)	0.051
	Magnesium (post-dialysis)	0.007 (0.000–0.772)	0.039*
	Bicarbonate (TCO_2)	0.920 (0.71–1.20)	0.538
	Ejection Fraction (%)	1.01 (0.87–1.17)	0.933
	LVMI (g/m²)	1.15 (0.91–2.99)	0.008*
	PASP (mmHg)	1.103 (0.83–1.99)	0.026*
Bradyarrhythmias	Age > 40 years	1.61 (0.51–5.09)	0.419
	Diabetes Mellitus	0.260 (0.07–0.886)	0.028*
Tachyarrhythmias	Age > 40 years	1.43 (0.43–4.69)	0.556
	Diabetes Mellitus	0.75 (0.22–2.51)	0.638
	PASP (mmHg) (comparison group)	–	0.042*

Table 7: Association of tachyarrhythmia with clinical and echocardiographic parameters in MHD patients (N = 49).

Variable	With Arrhythmia(n = 32)	Without Arrhythmia(n = 17)	p-value
Demographics & Comorbidities			
Age (years), Mean ± SD	40.8 ± 12.5	44.6 ± 11.8	0.300 ‡
Male sex	23 (71.88)	13 (76.47)	0.729 †
Diabetes mellitus	11 (34.38)	7 (41.18)	0.638 †
Hypertension	30 (93.75)	17 (100.00)	0.293 †
Echocardiographic Parameters			
LVMI (g/m²), Mean ± SD	126.8 ± 44.4	134.1 ± 48.4	0.601 ‡
PASP (mmHg), Mean ± SD	37.7 ± 15.1	29.4 ± 13.3	0.042* ‡
Ejection Fraction (%), Mean ± SD	59.3 ± 5.4	62.6 ± 5.2	0.044* ‡
Hemodialysis Parameters	With Arrhythmia(n = 42)	Without Arrhythmia(n = 7)	p-value
HD Access: AV Fistula	39 (92.86)	6 (85.71)	0.523 †
HD Access: Perm. Catheter	3 (7.14)	1 (14.29)	
HD Frequency: 2/week	33 (78.57)	6 (85.71)	0.664 †
HD Frequency: 3/week	9 (21.43)	1 (14.29)	

Table 8: Association between β-blocker use and occurrence of arrhythmias and bradycardia in the study population.

Variables	β-Blocker		p-value
	Yes	No	
Any Arrhythmia (n = 42)	31 (73.81)	11 (26.19)	0.018*
PAC (n = 38)	27 (71.05)	11 (28.95)	0.304
PVC (n = 35)	27 (77.14)	8(22.86)	0.021*
Tachyarrhythmia (n = 32)	22 (68.75)	10 (31.25)	0.774
Bradycardia (n = 29)	21 (72.41)	8 (27.59)	0.362

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with 75.51% of patients on dihydropyridine calcium channel blockers (DHP-CCBs), 67.35% on β-blockers, and 32.65% on α-blockers, consistent with treatment practices for CKD-associated hypertension and cardiovascular protection [30]. Patients had been on dialysis for a mean of 15.6±14.4 months, with the majority (79.59%) receiving dialysis twice weekly, suggesting resource limitations compared to international recommendations. Arteriovenous fistula (AVF) was the access of choice in 91.84% of patients, favoring long-term dialysis outcomes [26]. On dialysis days, patients experienced a mean ultrafiltration volume of 2.34±0.92 L and interdialytic weight gain of 2.39±0.95 kg. Blood pressure readings remained elevated (143.7±16.1 / 84.8±11.1 mmHg), indicating residual fluid overload [27]. Echocardiographic assessment revealed preserved ejection fraction in 95.92% (mean EF: 60.5±5.5%), but structural abnormalities were prevalent. The mean left ventricular mass index (LVMI) was 130.6±43.7 g/m², and LVIDD averaged 52.2±5.16 mm. Diastolic dysfunction was present in 24.5% (Grade 1 in 16.3%, Grade 2 in 6.1%, Grade 3 in 2%). Pulmonary artery systolic pressure (PASP) was elevated at 32.3±14.3 mmHg, reflecting increased cardiovascular strain and pulmonary hypertension risk [15]. Dialysis significantly improved several biochemical markers. Potassium levels declined from 4.67±0.64 to 4.16±0.55 mmol/L ($p < 0.001$), while TCO_2 rose from 20.53±3.39 to 25.45±2.68 mmol/L ($p = 0.001$), indicating effective electrolyte and acid-base regulation. Calcium increased ($p = 0.023$), and phosphate decreased significantly ($p = 0.014$). Serum magnesium decreased slightly but nonsignificantly ($p = 0.49$); however, post-dialysis magnesium was a significant predictor of PACs and PVCs, supporting its arrhythmia-protective role [31]. Holter monitoring identified a high prevalence of arrhythmias. PACs were observed in 77.55% of patients, with 10.53% exceeding 70 PACs/day. PVCs were present in 71.43%, though 94.29% had a burden <5% of total beats. Sinus bradycardia was found in 59.18%, and tachyarrhythmias in 65.31%, often occurring within the first six hours post-dialysis, suggesting a strong physiological trigger related to the dialysis procedure [35]. Multivariate logistic regression showed that post-dialysis magnesium was significantly associated with both PACs ($p = 0.004$) and PVCs ($p = 0.039$), and post-dialysis potassium was also a predictor of PVCs ($p = 0.033$). This underscores the importance of electrolyte stability in arrhythmia prevention [20, 31]. Increased PASP (OR = 1.103, $p = 0.026$) and LVMI (OR = 1.15, $p = 0.008$) were also significantly associated with PVCs, highlighting the contribution of structural heart changes to arrhythmogenic risk [37]. Diabetes mellitus was significantly associated with bradyarrhythmias (OR = 0.260, $p = 0.028$), reinforcing the role of autonomic dysfunction in diabetic patients [19]. In patients with tachyarrhythmia, PASP was significantly higher (37.7±15.1 mmHg vs. 29.4±13.3 mmHg; $p = 0.042$), and mean ejection fraction was significantly lower (59.3±5.4% vs. 62.6±5.2%; $p = 0.044$), further confirming cardiovascular remodeling as a driver of rhythm abnormalities. Beta-blocker use was significantly associated with an increased incidence of overall arrhythmias ($p = 0.018$) and PVCs ($p = 0.021$). This paradoxical finding may be related to the timing of administration relative to dialysis sessions or inadequate dosage titration, rather than a lack of efficacy [38]. No significant associations were found between arrhythmia prevalence and HD access type or frequency, suggesting that internal cardiovascular and metabolic factors may outweigh dialysis procedural aspects in arrhythmogenesis [39].

Limitations of the study: This study has several limitations. Dialysis adequacy was not individually assessed despite using the same dialyzer and solution. A more homogeneous population receiving thrice-weekly dialysis might yield more consistent results. Holter monitoring was limited to 24 hours, potentially underestimating arrhythmia burden. The study population was relatively young, which may not reflect the typical arrhythmia-prone demographic. Additionally, strict exclusion of patients with structural heart disease, regional wall motion abnormalities, and left ventricular dysfunction likely contributed to the lower incidence of detected arrhythmias.

Conclusion

This study was undertaken to evaluate the pattern and factors associated with cardiac rhythm disturbances in maintenance hemodialysis patients. In conclusion, maintenance hemodialysis patients experienced a high prevalence of both supraventricular and ventricular arrhythmias but their burden was very low. Premature atrial contractions (PACs) were more common than premature ventricular contractions (PVCs). While tachyarrhythmias occurred more often during and immediately after dialysis, bradyarrhythmias were found more in post dialytic period and increased with time. Patients with rigorous clearance of post dialysis potassium & magnesium were significantly associated with PACs & PVCs. Arrhythmias also found significantly associated with increased left ventricular mass index & pulmonary arterial systolic pressure.

Recommendations

Routine Holter monitoring is not necessary in asymptomatic hemodialysis patients without cardiac disease. Regular monitoring of serum magnesium and timely correction may reduce arrhythmia risk. Hemodialysis can be safely conducted in most patients with standard precautions. Further longitudinal studies are needed to evaluate the protective role of β-blockers.

Funding: No funding sources

Citation: Md. Saiful Ahammad Sarker, Asia Khanam, Md. Fakhrul Islam Khaled, S. M. Remin Rafi, Afrin Akter, Anjuman Ara Daisy, SK Afsana Hossain, H. M. Mohiuddin Alamgir, Mohammad Kamrul Hasan. Pattern and Predictors of Cardiac Rhythm Disturbances in Patients on Maintenance Hemodialysis. Archives of Nephrology and Urology. 8 (2025): 126-134.

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DOI:10.26502/anu.2644-2833106

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee.

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