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ORIGINAL ARTICLE

Asymptomatic Cardiac Arrhythmias in Maintenance Hemodialysis – Frequency, Causes, and Patterns

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ABSTRACT

Background: *Cardiac arrhythmias are a major cause of morbidity and mortality in patients undergoing maintenance hemodialysis (MHD). Many arrhythmias remain asymptomatic and undetected, contributing to sudden cardiac death. Understanding their frequency, patterns, and predictors is crucial for improving patient outcomes.* ***Aim of the study:*** *To determine the frequency, types, and possible clinical and biochemical predictors of asymptomatic cardiac arrhythmias among patients receiving maintenance hemodialysis.* ***Methods & Materials:*** *This cross-sectional observational study was conducted at the Department of Nephrology, BSMMU, Dhaka, from April 2023 to September 2024. A total of 49 adult MHD patients meeting inclusion criteria underwent 24-hour Holter monitoring and echocardiographic evaluation. Demographic, clinical, and biochemical parameters were recorded and analyzed using SPSS (version 26). Logistic regression was applied to identify predictors of arrhythmia.* ***Result:*** *Asymptomatic arrhythmias were detected in 77.6% (PACs), 71.4% (PVCs), 59.2% (bradycardia), and 65.3% (tachycardia) of patients. Most events occurred during or immediately after dialysis. Lower post-dialysis magnesium (OR 0.007, 95% CI: 0.00–0.77, p=0.039) and potassium levels (OR 0.11, 95% CI: 0.01–0.84, p=0.033) were significant predictors for ventricular ectopy. Other factors, including age, diabetes, hypertension, and LVMI, were not independently associated.* ***Conclusion:*** *Asymptomatic cardiac arrhythmias are common in MHD patients, with electrolyte fluctuations—particularly reduced post-dialysis magnesium and potassium—serving as key contributors. Routine Holter monitoring and individualized dialysis prescriptions may help in early detection and prevention of fatal arrhythmias.*

Keywords: *Maintenance hemodialysis, asymptomatic arrhythmia, Holter monitoring, magnesium, ventricular ectopy.*

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INTRODUCTION

Chronic kidney disease (CKD) is a growing public health burden and a significant contributor to global morbidity and mortality. Cardiac arrhythmia is a condition characterized by abnormal rate or rhythm of the heartbeat due to irregular electrical activity in the heart [1]. According to the Global Burden of Disease study, approximately 850 million people worldwide are affected by kidney diseases, and an estimated 2.6 million patients receive renal replacement therapy, including hemodialysis (HD), with numbers projected to double by 2030 [2]. In Bangladesh, CKD affects nearly 18% of the adult population, and access to maintenance HD has expanded in recent years, leading to a rising population vulnerable to dialysis-related complications [3]. Among patients undergoing maintenance hemodialysis (MHD), cardiovascular diseases (CVDs) remain the leading cause of death, accounting for approximately 40% to 50% of all mortalities [4]. Alarmingly, nearly half of these cardiovascular

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deaths are attributed to sudden cardiac death (SCD), which is frequently associated with underlying cardiac arrhythmias [5]. The increased cardiovascular vulnerability among HD patients is multifactorial, with mechanisms involving chronic volume overload, metabolic derangements, sympathetic overactivity, myocardial fibrosis, and dialysis-related hemodynamic instability [6]. A substantial proportion of cardiovascular events in MHD patients, including SCD, occur during or shortly after HD sessions, highlighting the potential arrhythmogenic nature of the dialysis process itself [7]. Episodes of intradialytic hypotension (IDH), occurring in up to one-third of outpatient HD treatments, have been linked to myocardial ischemia and stunning, which may serve as precursors for fatal arrhythmias [8]. These insights underscore the need to identify and mitigate modifiable risks like IDH in the dialysis population. Despite the clinical significance, the true burden of asymptomatic cardiac arrhythmias in HD patients remains underreported [9]. Most previous studies evaluating arrhythmic burden have relied on short-duration Holter monitoring and small sample sizes, conducted before major advances in cardiovascular care [10]. Additionally, the HD population has evolved significantly over the past decade, with patients now being older, more comorbid (especially with diabetes mellitus and hypertension), and exposed to different dialysis technologies and buffer systems [11]. The replacement of acetate with bicarbonate as a buffer and the reduction in the use of low-potassium dialysates have potentially altered arrhythmia risks [12]. Recent registries, such as the USRDS and DOPPS, report atrial fibrillation prevalence ranging from 7% to 27% in HD patients [13]. However, regional data, especially from South Asia and Bangladesh, remain sparse. Local evidence is essential as demographic, clinical, and dialysis-related practices differ significantly and may influence arrhythmia patterns [14]. Moreover, emerging studies suggest several independent risk factors for arrhythmias, including older age, low systolic BP, longer dialysis vintage, low serum calcium, and DM [15]. This study was therefore designed to assess the frequency, patterns, and possible clinical determinants of asymptomatic cardiac arrhythmias among patients with CKD receiving maintenance HD, using extended Holter monitoring and comprehensive clinical evaluation.

METHODS & MATERIALS

This was a cross-sectional observational study conducted in the Department of Nephrology at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. The study was carried out over an 18-month period from April 2023 to September 2024. A total of 49 adult patients with stage 5 chronic kidney disease (CKD) undergoing MHD for at least 3 months were consecutively enrolled.

Inclusion and Exclusion Criteria

Inclusion criteria comprised patients aged ≥18 years, receiving regular hemodialysis (2–3 sessions per week), and clinically stable without symptoms of arrhythmia. Patients with known structural heart disease, pacemakers, recent hospitalization, or current anti-arrhythmic therapy were excluded.

Data Collection

Demographic and clinical data, including age, sex, comorbidities (hypertension, diabetes, dyslipidemia), dialysis vintage, body mass index (BMI), and antihypertensive medication use, were recorded using a structured case record form. Laboratory parameters (serum electrolytes, hemoglobin, calcium, phosphate) were measured using standard automated analyzers. Dialysis-related data, including frequency and duration of sessions, were retrieved from institutional records.

Electrocardiographic Assessment

All participants underwent 24-hour ambulatory Holter monitoring using a 3-channel digital Holter device (model specified). The recordings were analyzed by an experienced cardiologist blinded to clinical data. Arrhythmias were classified as premature atrial contractions (PACs), premature ventricular contractions (PVCs), sinus bradycardia (<60 bpm), or sinus tachycardia (>100 bpm). Temporal distribution of arrhythmias was analyzed in four 6-hour blocks relative to the dialysis session.

Echocardiographic Evaluation

Transthoracic echocardiography was performed using a standard protocol (Philips/GE system) by a trained cardiologist. Parameters assessed included ejection fraction (EF), left ventricular mass index (LVMI), left ventricular internal diastolic diameter (LVIDD), diastolic dysfunction grading, pulmonary artery systolic pressure (PASP), and the presence of aortic sclerosis.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Logistic regression analyses were performed to identify independent predictors of arrhythmia subtypes. Odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding p-values were reported. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Review Board (IRB) of BSMMU (Approval No. IRB/BSMMU/2023/Nephro-101). Written informed consent was obtained from all participants. All procedures conformed to the ethical guidelines of the Declaration of Helsinki.

RESULT

The mean age of the patients was 42.1±12.3 years, with 53.06% above 40 years of age. Males predominated, accounting for 73.47% of the study population. The mean BMI was 23.6±4.8 kg/m^2. Hypertension was the most prevalent comorbidity (95.92%), followed by diabetes mellitus (36.73%) and dyslipidemia (12.24%). Regarding antihypertensive therapy, the most commonly prescribed drugs were DHP-CCB (75.51%), β-blockers (67.35%), and α-blockers (32.65%) (Table 1). Table 2 showed that all patients

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underwent standard dialysis sessions lasting 4.0±0.0 hours. Most participants (79.59%) received dialysis twice weekly, while 20.41% had thrice-weekly sessions. The mean pre-dialysis serum potassium was 4.67±0.64 mmol/L, which decreased to 4.16±0.55 mmol/L post-dialysis. The mean serum calcium and phosphate levels were 8.85±1.15 mg/dL and 4.51±1.09 mg/dL, respectively. Premature atrial contractions (PACs) were the most frequent (77.55%), followed closely by premature ventricular contractions (PVCs) in 71.43% of patients. Sinus tachycardia (>100 bpm) occurred in 65.31%, while sinus bradycardia (<60 bpm) was seen in 59.18% of individuals (Table 3). The mean ejection fraction was 60.5±5.5%, with 95.92% of patients maintaining normal systolic function (>50%). Mean LVMI was 130.6±43.7 g/m^2, and mean LVIDD was 52.2±5.16 mm. Aortic sclerosis was detected in 8.16%, and the mean pulmonary artery systolic pressure (PASP) was 32.3±14.3 mmHg (Table 4). Table 5 presented that during the dialysis period (0–6 hours), the highest frequencies of PACs (38.8%) and tachyarrhythmias (38.8%) were observed, whereas bradyarrhythmias (53.1%) peaked during the 18–24-hour period post-dialysis. PVCs were most frequent during the 0–6 hour (35.7%) and 18–24 hour (27.1%) intervals. Multivariate analysis identified post-dialysis magnesium level as a significant independent predictor for both PACs (OR 0.00, 95% CI: 0.00–0.03, p=0.004) and PVCs (OR 0.007, 95% CI: 0.00–0.77, p=0.039). Post-dialysis potassium (OR 0.11, p=0.033) and LVMI (OR 1.15, p=0.008) were also significantly associated with PVCs. PASP showed a positive correlation with PVCs (OR 1.10, p=0.026). Interestingly, diabetes mellitus appeared protective against bradyarrhythmias (OR 0.26, p=0.028). Other variables, including age, hypertension, and calcium levels, did not demonstrate significant associations (Table 6).

Table – I: Baseline demographic and clinical characteristics of patients on maintenance hemodialysis (*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
BMI (kg/m2)		
Mean ±SD	23.6±4.8	
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 – II: Dialysis-related and laboratory parameters of the study population

Parameter	Mean ± SD
Duration of each dialysis session (hours)	4.0 ± 0.0
Frequency of dialysis	
2 sessions	39 (79.59)
3 sessions	10 (20.41)
Pre-dialysis serum potassium (mmol/L)	4.67 ± 0.64
Post-dialysis serum potassium (mmol/L)	4.16 ± 0.55
Serum calcium (mg/dL)	8.85 ± 1.15
Serum phosphate (mg/dL)	4.51 ± 1.09
Hemoglobin (g/dL)	10.0 ± 1.23

Table – III: Frequency and types of asymptomatic cardiac arrhythmias detected by 24-hour holter monitoring

Arrhythmia Type	Frequency (n)	Percentage (%)
Premature Atrial Contractions (PACs)	38	77.55
Premature Ventricular Contractions (PVCs)	35	71.43
Sinus Bradycardia (<60 bpm)	29	59.18
Sinus Tachycardia (>100 bpm)	32	65.31

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Table – IV: 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 – V: Distribution of asymptomatic cardiac arrhythmias by time block in hemodialysis patients (*n*=49)

Time Block (h)	PACs (%)	PVCs (%)	Bradyarrhythmias (%)	Tachyarrhythmias (%)
0–6 (dialysis)	38.8	35.7	12.2	38.8
6–12	21.1	22.9	14.3	27.6
12–18	20.4	14.3	20.4	14.3
18–24	19.7	27.1	53.1	19.3

Table – VI: Logistic regression predictors for asymptomatic cardiac arrhythmias in maintenance hemodialysis patients (*n*=49)

Predictor	PACs OR (95% CI)	p-value	PVCs OR (95% CI)	p-value	Bradyarrhythmias OR (95% CI)	p-value	Tachyarrhythmias OR (95% CI)	p-value
Age > 40 years	0.42 (0.10–1.47)	0.208	0.37 (0.10–1.34)	0.124	1.61 (0.51–5.09)	0.419	1.43 (0.43–4.69)	0.556
Diabetes mellitus	3.27 (0.62–17.2)	0.147	1.67 (0.44–6.38)	0.453	0.26 (0.07–0.89)	0.028	0.75 (0.22–2.51)	0.638
Hypertension	3.70 (0.21–64.5)	0.34	2.62 (0.15–44.9)	0.493	2.10 (0.65–6.78)	0.21	1.18 (0.35–4.01)	0.797
Post-dialysis K^+	0.15 (0.01–2.11)	0.159	0.11 (0.01–0.84)	0.033	0.55 (0.10–3.07)	0.496	0.92 (0.23–3.61)	0.903
Post-dialysis Mg^{2+}	0.00 (0.00–0.03)	0.004	0.007 (0.00–0.77)	0.039	0.18 (0.03–1.00)	0.05	0.34 (0.06–1.89)	0.22
LV Mass Index (per g/m^2)	0.99 (0.97–1.01)	0.269	1.15 (0.91–2.99)	0.008	1.04 (0.99–1.09)	0.11	1.02 (0.97–1.07)	0.38
PASP (per mmHg)	0.99 (0.94–1.05)	0.784	1.10 (0.83–1.99)	0.026	1.03 (0.96–1.11)	0.39	1.05 (0.97–1.13)	0.22

DISCUSSION

The study reported a mean age of 42.1 ± 12.3 years and a mean BMI of 23.6 ± 4.8 kg/m^2, with a male predominance (73.47%). Hypertension was highly prevalent (95.92%), and 36.73% of the patients had diabetes mellitus. In a previous study, Ajmal et al. reported a higher mean BMI of 27.0 ± 6.2 kg/m^2, a mean age of 62.2 ± 13.8 years, male predominance (67.8%), and a high prevalence of hypertension (90.1%), with 21.7% of patients having diabetes mellitus [16]. In our study, patients underwent 4-hour dialysis sessions, predominantly twice weekly (79.59%). Pre-dialysis potassium averaged 4.67 ± 0.64 mmol/L and decreased to 4.16 ± 0.55 mmol/L, demonstrating effective removal. Calcium, phosphate, and hemoglobin levels remained within recommended ranges, indicating adequate metabolic and anemia management. Similarly, Ansari et al. reported a mean serum potassium of 3.8 ± 0.2 mmol/L at the time of arrhythmias [17], Roberts et al. observed a mean hemoglobin level of 11.8 ± 1.3 g/dL [18], and Chaudhury et al. noted that arrhythmias peaked during the first dialysis session and late inter-dialytic hours, with higher pre-dialysis sodium and dialysate calcium >2.5 mmol/L identified as key risk factors [19]. Asymptomatic arrhythmias were highly prevalent in this cohort. Premature atrial contractions (PACs) occurred in 77.55% of patients, premature ventricular contractions (PVCs) in 71.43%, sinus bradycardia in 59.18%, and sinus tachycardia in 65.31%. In previous studies, Roberts et al. reported PACs ranging from 40.3% to 100%, while PVCs were observed in 59.7% to 87.8% of patients. Sinus bradycardia showed considerable variability, documented in 20% to 59.18% of patients, and sinus tachycardia prevalence ranged from 2.5% to 65.31% across different studies [20]. Most patients (95.92%) had preserved left ventricular ejection fraction (mean 60.5±5.5%), while the mean left ventricular mass index (LVMI) was 130.6±43.7 g/m^2, indicating a high prevalence of left ventricular hypertrophy. Diastolic dysfunction was present in 24.49% of patients across grades 1 to 3. These findings corroborate previous reports that highlight structural cardiac changes as a common consequence of chronic kidney disease and HD [21]. Arrhythmia occurrence varied throughout the day. PACs (38.8%) and PVCs (35.7%) were most frequent during dialysis sessions, while bradyarrhythmias peaked (53.1%) in

the late post-dialysis period. This temporal pattern is consistent with prior studies showing that arrhythmias often occur during and after dialysis due to electrolyte shifts and hemodynamic changes [22]. Post-dialysis magnesium levels emerged as a significant predictor for PVCs (OR 0.007, 95% CI: 0.00–0.77, p=0.039), suggesting that lower magnesium levels may increase the risk of ventricular ectopy. Other factors, including age, diabetes, hypertension, post-dialysis potassium, LVMI, and pulmonary artery systolic pressure, were not significantly associated with arrhythmia risk. These findings underscore the complex interplay of electrolyte disturbances and structural heart changes in the pathogenesis of arrhythmias in HD patients [23].

Limitations of the Study:

This study was limited by its relatively small sample size and single-center design, which may restrict the generalizability of the findings. The cross-sectional nature precluded assessment of long-term arrhythmic outcomes or causal relationships. Additionally, electrolyte measurements were taken only before and after dialysis, not during the procedure, which may have missed transient changes. Use of 24-hour Holter monitoring might have underestimated arrhythmias occurring outside the recording period or on non-dialysis days.

CONCLUSION

Asymptomatic cardiac arrhythmias were found to be highly prevalent among patients receiving maintenance hemodialysis, with premature atrial and ventricular contractions being the most common types. The study demonstrates that electrolyte shifts, particularly post-dialysis magnesium and potassium levels, play a crucial role in arrhythmogenesis. Lower post-dialysis magnesium emerged as a significant independent predictor for ventricular ectopy, emphasizing the importance of maintaining optimal electrolyte balance during dialysis. Although age, diabetes, and hypertension were frequent comorbidities, they showed limited independent influence on arrhythmic patterns. These findings suggest that regular Holter monitoring and individualized dialysis prescriptions may help detect and prevent subclinical arrhythmias, thereby reducing the risk of sudden cardiac death in this vulnerable population.

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