Journal of Medical and Surgical Practice (JMSP)
ISSN: 2664-1704
Vol. 09, No. 03, July-September, 2023

Incidence and Associated Factors of Cardiac Arrhythmias among Uremic Patients Undergoing Hemodialysis

AbdAlmahdi Abdalrasul Fattah Al-Sallami[1*], Mohammed Jawad Kashkool Shubbar[2], Hasan Joodi Abbas.[3]

1, 2 & 3: MBChB, Diploma in Medicine, Najaf Health Directorate

* *Corresponding Author*

Original Article

Summary

Patients with end stage renal disease (ESRD) on hemodialysis exhibit the worst clinical outcomes. Arrhythmia is responsible for two thirds of cardiac deaths in these patients. It is necessary to adapt the most effective approaches for diagnosing, preventing, and treating Arrhythmias in ESRD patients. This was a prospective study aimed to estimate the incidence of cardiac arrhythmias among group of Iraqi patients with ESRD on hemodialysis. The study conducted in two main hospitals that had nephrology and dialysis units in Al-Najaf city during a period of 14 months included 60 patients with ESRD on regular hemodialysis. Patients with proved myocardial infarction or cardiomyopathies were excluded. Standards electrocardiography, echocardiography and all other necessary investigations were performed. Biochemical profile and electrolytes were also investigated accordingly. Arrhythmias that occurred before and during dialysis process were recorded. We documented that during HD, more arrhythmias had been developed among patients; 22 patients had PVC, 13 PAC and 4 developed other arrhythmias (rapid AF, VT). We found that hypocalcemia was significantly associated with developed cardiac arrhythmias. Additionally, patient who had PVC arrhythmias showed longer QTc (mean = 461.3±15.7 ms). In conclusions, cardiac arrhythmias were frequently occur in uremic patients during and after hemodialysis outside. It is multifactorial and can be attributed to cardiac stunning during heamodialysis or due to electrolyte disturbances.

Keywords: *End stage renal disease, Uremic Patients, Hemodialysis, Cardiac Arrhythmias*

Received : July 2023, **Published**: September 2023

Citation: Al-Sallami A.A.F, Shubber M.J.K, Abbas H.J Incidence and Associated Factors of Cardiac Arrhythmias among Uremic Patients Undergoing Hemodialysis. JMSP 2023; 9(3): 172-188

1. INTRODUCTION

Chronic kidney disease (CKD) represents a significant public health problem worldwide. It is characterized by a persistent impairment in renal structure or function that persists for a duration beyond three months, hence carrying significant health implications. Chronic kidney disease (CKD) is categorized based on its etiology and the extent of kidney damage as determined by the glomerular filtration rate (GFR) (ranging from G1 to G5). Furthermore, a subcategory is included to indicate the degree of albuminuria (A1, A2, A3) due to its significant association with cardiovascular disease risk and CKD severity (G1-5A1-A3) (1). The changes in the prevalence of CKD is exemplified by the current global impact, with more than 800 million individuals affected by this condition. The prevalence CKD is higher in older age population, females, racial minorities, diabetic and hypertensive patients. CKD has become a prominent contributor to global mortality rates, ranking among the few non-communicable diseases that have exhibited a rise in mortality rates over the last two decades. The substantial prevalence of affected persons and the considerable negative consequences of chronic renal disease necessitate intensified efforts to improve preventative and treatment strategies (2). Moreover, projections indicate that CKD will ascend to become the fifth leading cause of early mortality by the year 2040 (3). Currently, CKD owing to its substantial financial burden particularly in developing countries. For instance, dialysis therapy consumes almost 2-3% of the yearly healthcare budget in developed countries while it has large financial burden and cost in low and middle income countries as dedicated to dialysis and kidney transplantation which further highlighting the economic impact of CKD in these countries (4,5). There is a high variability and heterogeneity in CKD composition and the global prevalence and mortality of CKD. Among individuals aged 20 years and older, the age-standardized global prevalence of CKD stages 1-5 was found to be 10.4% among men and 11.8% among women, for stages 3-5 the prevalence ranged between 4.7% in men and 5.8% in women with a significant variations based on geographical location and income classification. In high-income nations, the age-standardized prevalence of chronic kidney disease (CKD) was 8.6% for men and 9.6% for women. In low- and middle-income countries, the corresponding figures were 10.6% for males and 12.5% for women (6,7). Many risk factors associated with CKD such as genetic factors and family history, male gender, ethnicity, older age, obesity, smoking, nephrotoxins, acute

kidney injury, hypertension, diabetes mellitus (8). In patients with CKD, dialysis is indicated and the decision to initiate dialysis include subjective and objective parameters. Among the clinical indications to initiate dialysis in patients with CKD pericarditis or pleuritis, represent an urgent indication. Progressive uremic encephalopathy or neuropathy, a clinically significant bleeding diathesis attributable to uremia (urgent indication), fluid overload refractory to diuretics, hypertension poorly responsive to antihypertensive medications, persistent metabolic disturbances and evidence of malnutrition all represent the absolute indications, however, some other relative indications include decreased attentiveness and cognitive tasking, depression, persistent pruritus and restless leg syndrome (9,10). There are numerous complications that can arise from chronic kidney disease (CKD) itself or as a result of undergoing dialysis. During hemodialysis, individuals may experience various complications, including technical issues with vascular access, hypotension, muscle cramps, nausea and vomiting, headache, agitation, cough, chest pain, infections and sepsis related to vascular access, dyspnea, myocardial ischemia, pericardial tamponade, arrhythmias, active bleeding, air embolism, and itching. Furthermore, long-term complications of CKD and dialysis such as anemia, elevated levels of parathyroid hormone, malnutrition and cardiovascular diseases are commonly occurred in CKD patients (11,12). Cardiovascular diseases accounts for approximately 40% of all deaths among CKD patients particularly those on dialysis. Sudden cardiac death might be responsible for up to 60% of deaths in dialysis cases(11,12). Cardiac arrhythmias are generally produced by one of three mechanisms: enhanced automaticity, triggered activity, or reentry. Reentry is the electrophysiologic mechanism responsible for most of the clinically important arrhythmias, including atrial fibrillation, atrial flutter, atrioventricular (AV) nodal reentry, AV reentry involving a bypass tract, ventricular tachycardia after myocardial infarction and ventricular fibrillation. Arrhythmia-related fatalities accounted for 58% of cardiac deaths in peritoneal dialysis patients and 64% of cardiac deaths in hemodialysis patients. The prevalence of cardiac arrhythmias among dialysis patients was reported to be 62 per 1,000 patient-years at risk. This figure represents 26% of the total number of fatalities. Furthermore, it is worth noting that among the demographic of elderly individuals undergoing dialysis, the incidence rate was recorded at 93.7 per 1,000 patient-years. Atrial fibrillation (AF) is a commonly seen cardiac arrhythmia in clinical settings. Around 14% - 27% of individuals with ESRD who undergo

hemodialysis (HD) exhibit chronic AF (including paroxysmal, persistent, and permanent forms), and the incidence increases with age (13,14). Diagnosis of cardiac arrhythmia in patients undergoing hemodialysis (HD) often based on electrocardiogram (ECG), and the occurrence of arrhythmias tends to rise during and shortly following the HD procedure. The utilization of Holter electrocardiogram (ECG) monitoring for a duration of 24 hours is an additional approach employed in the assessment of cardiac arrhythmias (15). Chronic uremia is known to be associated with a high burden of sympathetic drive and RAAS activation. Therefore, control of sympathetic outflow and blockade of the RAAS should be the mainstay of CV disease prevention in ESRD, although no high-grade evidence is available. Initial therapy for AF is often directed toward the maintenance of sinus rhythm by means of cardioversion and the use of antiarrhythmic drugs. The rationale for this "rhythmcontrol" approach includes fewer symptoms, better exercise tolerance, a lower risk of stroke, an eventual discontinuation of long-term anticoagulant therapy, better quality of life and better survival, if sinus rhythm can be maintained(15). The aim of our study is to assess the types of arrhythmias during hemodialysis in uremic patients

2. PATIENTS and METHODS

This was a prospective study conducted during a period of 14 months at two hospitals in Al-Najaf city; Al-Najaf Teaching Hospital and Al-Hakeem General Hospital, both hospital with nephrology and dialysis units. The study included 60 patients who were consequently recruited.

Inclusion criteria:

1. Adult Iraqi uremic patients on regular hemodialysis
2. Both genders

Exclusion criteria:

1. Proved myocardial infarction
2. Cardiomyopathy

However, we did not exclude the patients according to their positivity of virology screen, duration of hemodialysis and the first time of dialysis.

Study Protocol:

A 12-lead standards electrocardiography (ECG) was performed for all patients in accordance with the standard criteria of clinical guidelines to provide a comprehensive assessment. The QT interval was determined in lead II. The QT-interval was adjusted in all cases using Bazett's formula (16) where :

$$QTc = QT / \sqrt{RR}$$

Two dimensional echocardiography was done for all patients by the same expert echo-cardiologist aiming to assess for pericardial effusion and ejection. Holter monitoring (Schiller) has been done half an hour before hemodialysis and during hemodialysis. The Holter monitoring results were assessed by the same specialist who was responsible for the Holter Study Unit. All arrhythmias and their frequencies before and during dialysis process were recorded. A sample of venous blood was taken from all patients under aseptic condition and sent to the laboratory for Biochemical tests and electrolyte assessment including sodium, calcium, potassium and phosphate in addition to blood urea and serum creatinine. Moreover, packed cell volume (PCV) was also investigated.

Statistical analysis:

Data of the patients were recorded in a pre-constructed data collection sheet, then transferred into computerized database using the Microsoft Excel program. After data collection was completed, statistical analysis was conducted using the statistical package for social sciences version 20. Descriptive and analytic statistics were performed accordingly and appropriate statistical tests were performed accordingly at a level of significance of 0.05.

3. RESULTS

Mean age was 44.6 ± 10.9 (range: 25 – 75) years, male patients were 37 (61.7%) with a male to female ratio of 1.6 to one. The mean duration of dialysis was 16.9 ± 9.3 (range: 1 – 37) months, (**Table 1**). Hypertension and DM reported in 78.3% and 51.7% of the studied group, respectively. Ejection fraction was less than 55 in 31.7%, LVH documented in 58.3%, chronic slow AF in 3 patients (5%) and pericardial effusion found in 33.3% of the patients, (**Table 2**).

The types of arrhythmias before and during hemodialysis (HD) are shown in (**Table 3**), PVC was the commonest type, before HD, 7 patients had PVC, 3 had PAC and none had other arrhythmias. During HD, more arrhythmias had been developed among patients; 22 patients

had PVC, 13 PAC and 4 developed other arrhythmias (rapid AF, VT). Further analyses were performed to assess the effect of different factors and parameters on the development of arrhythmias, cross-tabulation between these factors from one side against each type of arrhythmias from the other side was performed and revealed that B.urea , serum creatinine, serum potassium , serum sodium, serum phosphorus and hemoglobin have no statistically significant effect on the occurrence of cardiac arrhythmia during hemodialysis. Serum calcium has statistically significant effect on the occurrence of PVC, where 16 of 22 (72.7%) patients who developed PVC have hypocalcemia, P-value = 0.028, (**Tables 4, 5 & 6**). From other point of view, long QTc interval (>460 ms) reported in 26 patients contributed for 43.3%. In patients who developed PAC, QTc interval ranged between 422-482 ms with a mean of 450.2 ± 22.9 ms. Five of these patients have long QTc. However, no significant correlation between QTc interval versus B.urea and S.creatinine for patients who developed PAC, (P. value > 0.05), While the patients who developed PVC, the QTc interval was ranging from 439-484 ms and the mean was 461.3±15.7 ms, 12 of 22 patients (60%) were found to have long QTc interval. There was statistically significant correlation between QTc interval versus B.urea and S.creatinine for patients who developed PVC, their P-values were 0.036 and 0.029, respectively (**Table 7 and Figures 1,2,3&4**).).

Table 1. Baseline characteristics of the studied group (N=60)

Variable		No.	%
Age (year)	≤ 30	7	11.7
	31 - 40	20	33.3
	41 - 50	18	30.0
	> 50	15	25.0
	Mean (SD)	44.6 (10.9)	-
	Range	25 – 73	-
Gender	Male	37	61.7
	Female	23	38.3
Duration on Hemodialysis (month)	Mean (SD)	16.9 (9.3)	-
	Range	1.0 - 37	-

Table 2. Distribution of comorbidities and clinical findings of the studied group (N=60)

Variable		No	%
Hypertension	Yes	47	78.3
	No	13	21.7
DM	Yes	31	51.7
	No	29	48.3
EF (%)	≥ 55	41	68.3
	< 55	19	31.7
LVH	Yes	35	58.3
	No	25	41.7
Chronic slow AF	Yes	3	5.0
	No	57	95.0
Pericardial effusion	Yes	20	33.3
	No	40	66.7

Table 3. Types of arrhythmias before and during hemodialysis (HD)

Arrhythmias	Before HD		During HD	
	No.	%	No.	%
PVC	7	11.7	22	36.7
PAC	3	5.0	13	21.6
Others (Rapid AF , VT)	0	0.0	4	6.7
None	50	83.3	21	35.0
Total	60	100.0	60	100.0

Table 4. Relationship between different factors and PVC arrhythmias occurred during HD among the studied group

Variable		Total No. of patients (N=60)		PVC (n= 22)		P. value
		No.	%	No.	%	
S. Potassium (K^+) (mmol/L)	< 3.5	4	6.7	3	13.6	0.232 ns
	3.5 - 5.1	17	28.3	5	22.7	
	> 5.1	39	65.0	14	63.6	
S. Sodium (Na^+) (mmol/L)	<135	14	23.3	12	54.5	0.307 ns
	135 - 145	45	75.0	10	45.5	
	> 145	1	1.7	0	0.0	
S. Calcium (Ca^{++}) (mmol/L)	< 1.0	33	55.0	16	72.7	0.028 sig
	1.0-1.32	26	43.3	6	27.3	
	> 1.32	1	1.7	0	0.0	
S. Phosphorus (mg/dL)	< 2.48	0	0.0	0	0.0	0.649 ns
	2.48-4.34	17	28.3	7	31.8	
	> 4.34	43	71.7	15	68.2	
Blood urea (mg/dL)	≤ 40	0	0.0	0	0.0	-
	> 40	60	100.0	22	100.0	
Serum creatinine (mg/dL)	≤ 1.36	0	0.0	0	0.0	-
	> 1.36	60	100.0	22	100.0	
HGB (g/dL)	≥ 11.5	11	18.3	3	13.6	0.474 ns
	< 11.5	49	81.7	19	86.4	

Table 5. Relationship between different factors and PAC arrhythmias occurred during HD among the studied group

Variable		Total No. of patients (N=60)		PAC (n= 13)		P. value
		No.	%	No.	%	
S. Potassium (K^+) (mmol/L)	< 3.5	4	6.7	1	7.7	0.890 ns
	3.5 - 5.1	17	28.3	3	23.1	
	> 5.1	39	65.0	9	69.2	
S. Sodium (Na^+) (mmol/L)	<135	14	23.3	2	15.4	0.628 ns
	135 - 145	45	75.0	11	84.6	
	> 145	1	1.7	0	0.0	
S. Calcium (Ca^{++}) (mmol/L)	< 1.0	33	55.0	8	61.5	0.780 ns
	1.0-1.32	26	43.3	5	38.5	
	> 1.32	1	1.7	0	0.0	
S. Phosphorus (mg/dL)	< 2.48	0	0.0	0	0.0	0.635 ns
	2.48-4.34	17	28.3	3	23.1	
	> 4.34	43	71.7	10	76.9	
Blood urea (mg/dL)	≤ 40	0	0.0	0	0.0	-
	> 40	60	100.0	13	100.0	
Serum creatinine (mg/dL)	≤ 1.36	0	0.0	0	0.0	-
	> 1.36	60	100.0	13	100.0	
HGB (g/dL)	≥ 11.5	11	18.3	3	23.1	0.617 ns
	< 11.5	49	81.7	10	76.9	

Table 6. Relationship between different factors and Other (Rapid AF , VT) arrhythmias occurred during HD among the studied group

Variable		Total No. of patients (N=60)		Rapid AF /VT (n= 4)		P. value
		No.	%	No.	%	
S. Potassium (K^+) (mmol/L)	< 3.5	4	6.7	0	0.0	0.821 ns
	3.5 - 5.1	17	28.3	1	25.0	
	> 5.1	39	65.0	3	75.0	
S. Sodium (Na^+) (mmol/L)	<135	14	23.3	0	0.0	0.704 ns
	135 - 145	45	75.0	4	100.0	
	> 145	1	1.7	0	0.0	
S. Calcium (Ca^{++}) (mmol/L)	< 1.0	33	55.0	2	50.0	0.772 ns
	1.0-1.32	26	43.3	2	50.0	
	> 1.32	1	1.7	0	0.0	
S. Phosphorus (mg/dL)	< 2.48	0	0.0	0	0.0	0.363 ns
	2.48-4.34	17	28.3	0	0.0	
	> 4.34	43	71.7	4	100.0	
Blood urea (mg/dL)	≤ 40	0	0.0	0	0.0	-
	> 40	60	100.0	4	100.0	
Serum creatinine (mg/dL)	≤ 1.36	0	0.0	0	0.0	-
	> 1.36	60	100.0	4	100.0	
HGB (g/dL)	≥ 11.5	11	18.3	0	0.0	0.335 ns
	< 11.5	49	81.7	4	100.0	

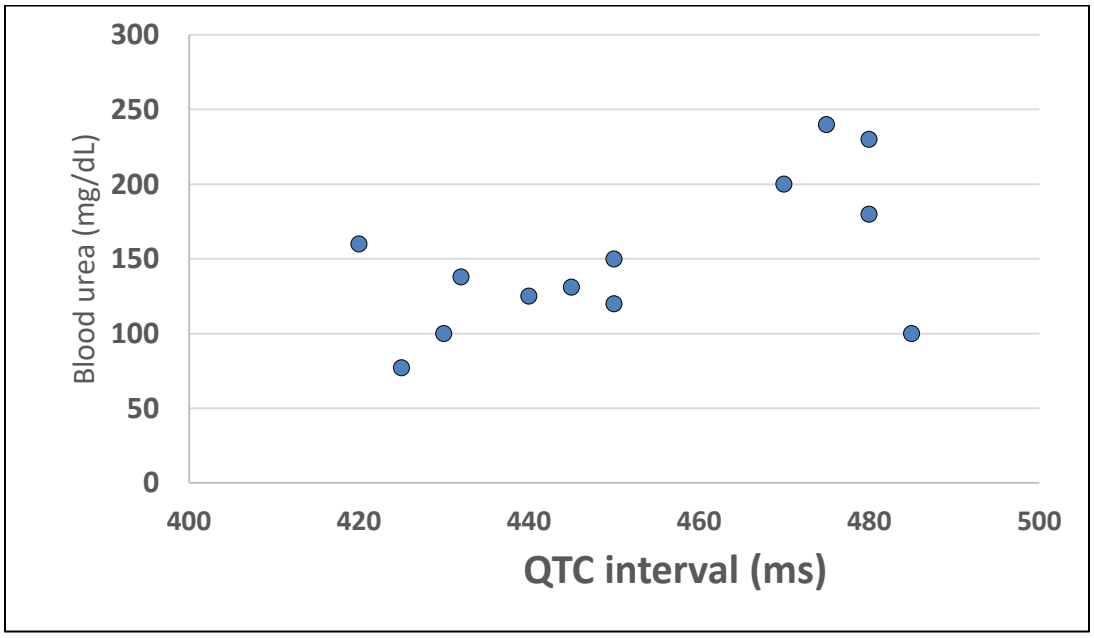

Figure 1. The correlation between QTc interval versus blood urea in patients who developed PAC during hemodialysis

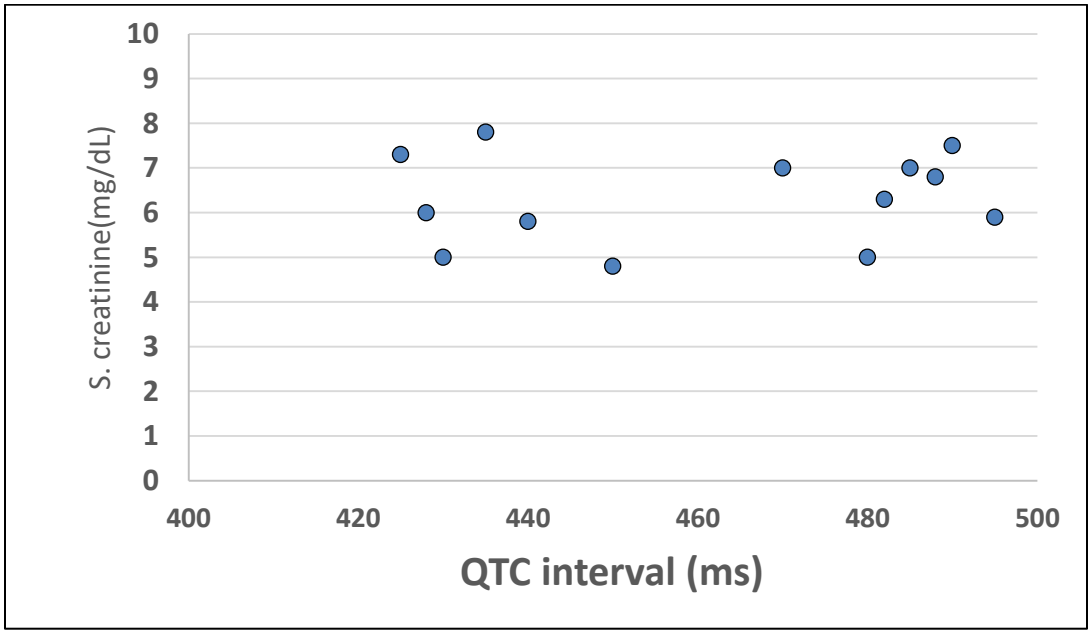

Figure 2. The correlation between QTc interval versus serum creatinine in patients who developed PAC during hemodialysis.

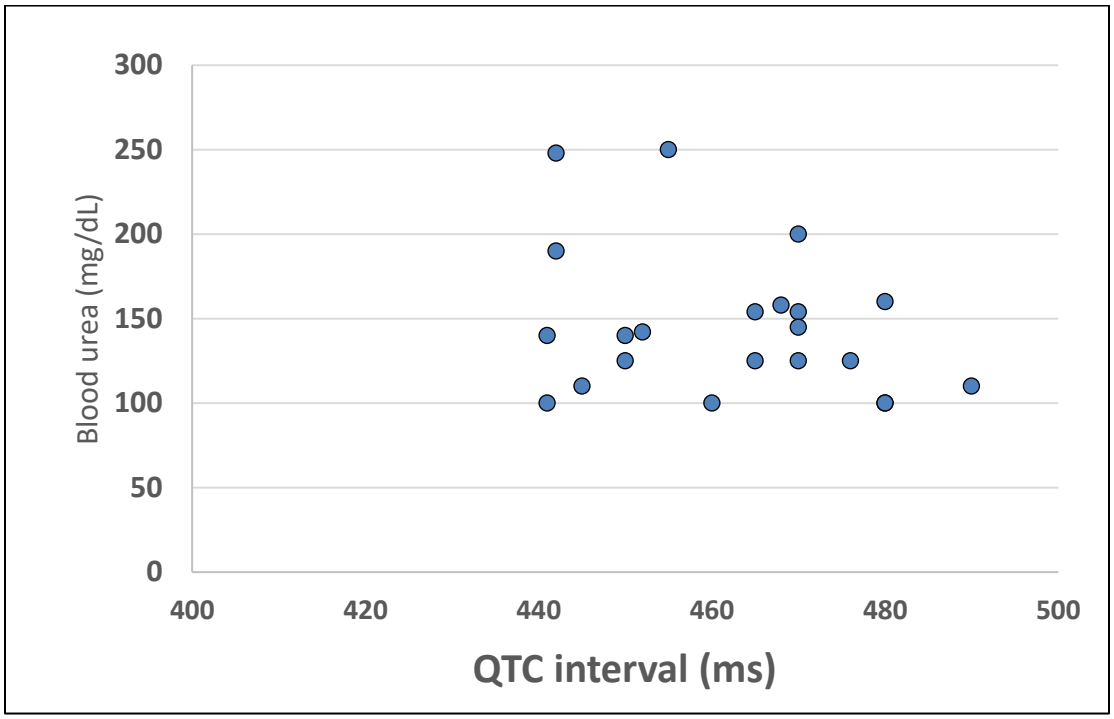

Figure 3. The correlation between QTc interval versus blood urea in patients who developed PVC during hemodialysis

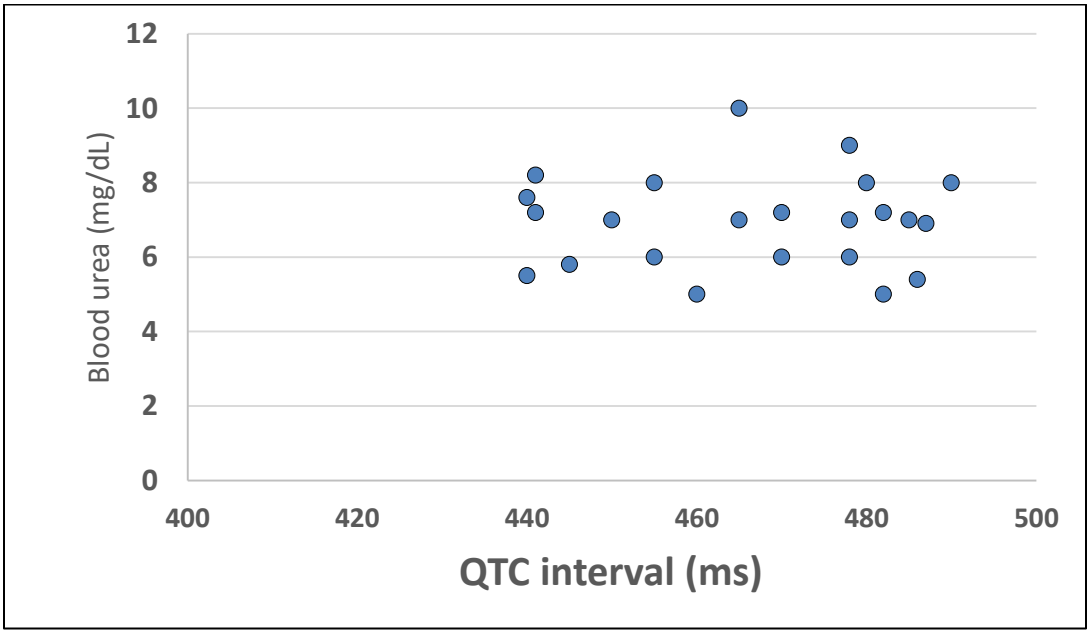

Figure 4. The correlation between QTc interval versus serum creatinine in patients who developed PAC during hemodialysis

4. DISCUSSION

Chronic kidney failure (CKD) is linked to a substantial rise in the likelihood of CVD and death, regardless of the existence of conventional cardiovascular risk factors. Patients CKD show a greater incidence of IHD, CHF and others. Reduced GFR is an indicator of ischemic events. As the ESRD patients undergoing dialysis have the most profound renal dysfunction, they exhibit the worst clinical outcomes compared to individuals with other forms of renal dysfunction(17–19). HD patients showed elevated rates of both cardiovascular and all-cause mortality. Arrhythmia is responsible for two thirds of cardiac deaths, accounting for 26% of overall mortality. However, the lack of long-term cardiac rhythm monitoring has historically restricted the availability of data regarding the extent of arrhythmia burden, the specific types of arrhythmias, the triggers for arrhythmias, and the identification of arrhythmias (19,20). The suboptimal results shown in clinical studies focusing on cardiovascular disease in patients with ESRD underscore the significant opportunity for enhancing outcomes. Therefore, it is necessary to adapt the most effective approaches for diagnosing, preventing, and treating CVD in ESRD patients (17–19). Hence this study conducted to estimate the incidence of cardiac arrhythmias among group of Iraqi patients with ESRD on hemodialysis in AlNajaf city, middle of Iraq. The hemodialysis duration in our study ranging from 1-38 months with mean of 17.3 months which is lower than other studies like Nasri et al study (21). this may reflect the high mortality rate in uremic patients who are on regular hemodialysis that resulted from high morbidity because of inadequate duration of hours of hemodialysis for each patient that resulted in inadequate decrease in blood urea and serum creatinine, electrolytes disturbance and generally ill health in high percentage of those patients. QTc interval was prolonged in 43.3% patients in our study. Patients who had more arrhythmia had higher QTc interval (22). Hypocalcaemia can increase QT interval and can increase arrhythmia Also dialysis-induced myocardial stunning was associated with an increased rate of intra-dialysis and post-dialysis ventricular arrhythmias There was a high incidence of PVC during hemodialysis, however, HD itself was not significantly contribute to this higher occurrence of PVC, but from other side, a significant association was found between hypocalcaemia and the incidence of PVC (21,23,24). Also 12 of 20 patients (60%) who developed PVC during hemodialysis were found to have long QTc interval. We found s statistically significant correlation between QTc interval

and each of B. urea and S. creatinine in those patients. This higher frequency of PVC during HD indicated an effect of hypocalcemia on the ventricular myocardial muscle membrane stability and action potential by altering QT interval. The explanation of no statistical significance of the hemodialysis on the occurrence of PVC could be attributed to the influence of other factors. Hemodialysis is potentially arrhythmogenic procedure in patients with preexisting cardiac disease (17,20,21) and the generally low occurrence of other types of arrhythmias including life threatening types is due to exclusion of the patients with myocardial infarction, cardiomyopathy and valvular heart disease in our study. The PAC occurred in some patients but did not show significant association with multiple factors and also there was no significant correlation between QTc interval versus B. urea and Creatinine for patients who developed PAC, because the long QT-interval affect mainly ventricular muscle. It was found that the PVC and PAC are the most common arrhythmias occurred before and during hemodialysis in our study. Patients with chronic slow AF represented (6.6%) in our study. The hemodialysis did not lead to occurrence of new AF and no statistically significant effect on the occurrence of rapid AF that developed in the two patients who are already have chronic AF. The rapid AF that developed in those patients reflected the stress on the heart whether by the excess volume of ultrafilteration during hemodialysis or the hypovolemia resulted from aspirated blood to the dialysis set in severely anemic patient who cannot tolerate more blood loss that lead to tachycardia (which in chronic AF patient expressed as rapid AF). The number of patients with low hemoglobin levels (<11.5gm/dL) in our study was 51 patients (85%). Anemia can worse the myocardial ischemia and leads to arrhythmia (25), however in our study, anemia has no significant statistical effect on occurrence of any type of cardiac arrhythmia during hemodialysis, but surely it affect general health and activity of uremic patients.

5. CONCLUSIONS

Cardiac arrhythmia can occur in uremic patients whether during hemodialysis or outside its time ,it is multifactorial , due to cardiac stunning during heamodialysis or due to electrolyte disturbances. To prevent the occurance of these complications during heamodialysis , the uremic patients must have more duration of heamodialysis sessions to blood urea,creatinin,electrolytes and improove general health. The patients also need frequent electrolytes monitoring to correct calicium deficit, Correction of anemia , nutritional statous and treatment of infections also play a major role in improoving the quality of life in uremic patients.

Ethical Clearance:

Ethical issues were taken from the research ethics committee. Informed consent was obtained from each participant. Data collection was in accordance with the World Medical Association (WMA) declaration of Helsinki for the Ethical Principles for Medical Research Involving Human Subjects, 2013 and all information and privacy of participants were kept confidentially.

Conflict of interest: Authors declared none

Funding: None, self-funded by the authors

6. *REFERENCES*

1. *Wheeler DC, Winkelmayer WC. KDIGO 2017 clinical practice guideline update for the diagnosis, evaluation, prevention, and treatment of chronic kidney disease-mineral and bone disorder (CKD-MBD) foreword. Kidney Int Suppl. 2017;7(1):1–59.*
2. *Kovesdy CP. Epidemiology of chronic kidney disease: an update 2022. Kidney Int Suppl. 2022 Apr;12(1):7–11.*
3. *Ortiz A. RICORS2040: the need for collaborative research in chronic kidney disease. Vol. 15, Clinical kidney journal. Oxford University Press; 2022. p. 372–87.*
4. *Mushi L, Marschall P, Fleßa S. The cost of dialysis in low and middle-income countries: a systematic review. BMC Health Serv Res [Internet]. 2015;15(1):506. Available from: https://doi.org/10.1186/s12913-015-1166-8*
5. *Li PKT, Chan GCK, Chen J, Chen HC, Cheng YL, Fan SLS, et al. Tackling dialysis burden around the*

world: A global challenge. Kidney Dis. 2021;7(3):167–75.

6. *Mills KT, Xu Y, Zhang W, Bundy JD, Chen CS, Kelly TN, et al. A systematic analysis of worldwide population-based data on the global burden of chronic kidney disease in 2010. Kidney Int. 2015;88(5):950–7.*
7. *Hill NR, Fatoba ST, Oke JL, Hirst JA, O'Callaghan CA, Lasserson DS, et al. Global prevalence of chronic kidney disease–a systematic review and meta-analysis. PLoS One. 2016;11(7):e0158765.*
8. *Kazancioğlu R. Risk factors for chronic kidney disease: an update. Kidney Int Suppl [Internet]. 2013;3(4):368–71. Available from: https://www.sciencedirect.com/science/article/pii/S2157171615311734*
9. *Daugirdas JT, Blake PG, Ing TS. Handbook of dialysis. Vol. 236. Lippincott Williams & Wilkins; 2007.*
10. *Initiative NKFOQ. Clinical Practice Guidelines and Clinical Practice Recommendations, 2006 Updates. Hemodialysis Adequacy.*
11. *Blagg CR. Long-term complications in hemodialysis. Vol. 12, Saudi Journal of Kidney Diseases and Transplantation. Medknow; 2001. p. 487–93.*
12. *Tzanakaki E, Boudouri V, Stavropoulou A, Stylianou K, Rovithis M, Zidianakis Z. Causes and complications of chronic kidney disease in patients on dialysis. Heal Sci J. 2014;8(3):343.*
13. *Genovesi S, Vincenti A, Rossi E, Pogliani D, Acquistapace I, Stella A, et al. Atrial fibrillation and morbidity and mortality in a cohort of long-term hemodialysis patients. Am J Kidney Dis. 2008;51(2):255–62.*
14. *Vázquez E, Sánchez-Perales C, Borrego F, Garcia-Cortés MJ, Lozano C, Guzmán M, et al. Influence of atrial fibrillation on the morbido-mortality of patients on hemodialysis. Am Heart J. 2000;140(6):886–90.*
15. *Di Lullo L, House A, Gorini A, Santoboni A, Russo D, Ronco C. Chronic kidney disease and cardiovascular complications. Heart Fail Rev. 2015;20:259–72.*
16. *Roguin A. Henry Cuthbert Bazett (1885–1950)—the man behind the QT interval correction formula. Pacing Clin Electrophysiol. 2011;34(3):384–8.*
17. *Aoki J, Ikari Y. Cardiovascular disease in patients with end-stage renal disease on hemodialysis. Ann Vasc Dis. 2017;10(4):327–37.*
18. *Nishizawa Y, Koyama H, Inaba M. AGEs and cardiovascular diseases in patients with end-stage renal diseases. J Ren Nutr. 2012;22(1):128–33.*
19. *Voroneanu L, Covic A. Arrhythmias in hemodialysis patients. JN J Nephrol. 2009;11(6):716.*

20. Charytan DM, Foley R, McCullough PA, Rogers JD, Zimetbaum P, Herzog CA, et al. Arrhythmia and Sudden Death in Hemodialysis Patients: Protocol and Baseline Characteristics of the Monitoring in Dialysis Study. Clin J Am Soc Nephrol. 2016 Apr;11(4):721–34.
21. Nasri H, Sarvar Azimzadeh B, Torabinejad M, Pourakbari R. Cardiac arrhythmia in dialysis patients. ARYA Atheroscler J. 2010;3(4).
22. O'Neal WT, Singleton MJ, Roberts JD, Tereshchenko LG, Sotoodehnia N, Chen LY, et al. Association between QT-interval components and sudden cardiac death: the ARIC study (Atherosclerosis Risk in Communities). Circ Arrhythmia Electrophysiol. 2017;10(10):e005485.
23. Nijjer S, Ghosh AK, Dubrey SW. Hypocalcaemia, long QT interval and atrial arrhythmias. Case Reports. 2010;2010:bcr0820092216.
24. Tang JKK, Rabkin SW. Hypocalcemia-induced QT interval prolongation. Cardiology. 2022;147(2):191–5.
25. Kaiafa G, Kanellos I, Savopoulos C, Kakaletsis N, Giannakoulas G, Hatzitolios AI. Is anemia a new cardiovascular risk factor? Int J Cardiol. 2015;186:117–24.