Pattern and possible contributing factors to dialysis-associated arrhythmia in young patients

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أنماط العوامل المساهمة باضطرابات النَظْم القلبية المرافقة للغسيل الكلوي والعوامل المحتملة المساهمة في حدوثها لدى الشباب المرضى

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الخلاصة: درس الباحثون اضطرابات النَظْم القلبية المرافقة للغسيل الكلوي لدى 48 مرضى ممن تقل أعمارهم عن 35 عاماً وكانوا يجرون الغسيل الكلوي بسبب اليوريميا لمدة تزيد على 3 شهور. وقد أوضحت الموجودات في جهاز المراقبة لهولتز وجود اضطرابات النَظْم القلبية البسيطة فقط، فقد لوحظ لدى 42٪ منهم اضطرابات نَظْم بطينية، ولدى 38٪ منهم اضطرابات نَظْم بطينية، وكما لوحظ انخفاض في القطعة ST بمقدار يزيد على 1 مليمتر لدى 58٪ من المرضى، كان لدى 80٪ منهم اضطرابات نَظْم، وعانى 38٪ منهم من ألم خناق الصدر. وقد سبب الغسيل الكلوي زيادة يعتد بها في طول القطع QTdc، QTc ومستوى الكالسيوم، وبقي مستوى البوتاسيوم منخفضاً. وقد كان لدى المرضى الذين أصيبوا باضطراب النَظْم القلبي خلال الغسيل الكلوي زيادة في كلٍ من كتلة البطين الأيسر ومنسب كتلة البطين الأيسر، ونقص في مستوى البوتاسيوم تلو الغسيل الكلوي، وزيادة في طول QTdc، QTc قبل وبعد الغسيل الكلوي. وكان لدى هؤلاء المرضى ارتفاع الضغط أكثر شيوعاً. وقد كان الانخفاض في قطعة ST مرتبط بدرجة يعتد بها إحصائياً باضطرابات النَظْم القلبية البطينية.

ABSTRACT We studied dialysis-associated arrhythmia in 48 uraemic patients < 35 years on chronic haemodialysis (HD) (> 3 months). Holter findings showed only minor arrhythmia; atrial in 42% of patients and ventricular in 38%. ST-segment depression > 1 mm was observed in 58% of patients; 80% had arrhythmia, and 36% experienced anginal pain. HD caused a significant increase in QTc, QTdc and Ca^{2+} level, while K^{+} level was significantly decreased. Patients who experienced arrhythmia during HD had higher left ventricular mass and left ventricular mass index, lower post-dialysis K^{+} level, higher QTc and QTdc both before and after HD. They were more frequently hypertensive. ST-segment depression was significantly related to ventricular arrhythmia.

Caractéristiques de l'arythmie associée à la dialyse chez de jeunes patients et facteurs susceptibles d'y contribuer

RÉSUMÉ Nous avons étudié l'arythmie associée à la dialyse chez 48 patients urémiques âgés de moins de 35 ans en hémodialyse (HD) chronique (> 3 mois). Les résultats du holter n'ont montré qu'une légère arythmie, atriale chez 42 % des patients et ventriculaire chez 38 %. Une dépression du segment ST > 1 mm a été observée chez 58 % des patients ; 80 % présentaient une arythmie et 36 % ressentaient une douleur angineuse. L'hémodialyse provoquait une augmentation significative des niveaux de QTc, de dispersion du QTc et de Ca^{2+}, alors que le niveau de K^{+} avait nettement diminué. Les patients atteints d'arythmie pendant la HD présentaient une augmentation de la masse ventriculaire gauche et avaient un indice de masse ventriculaire plus élevé, un niveau de K^{+} plus faible après la HD et des niveaux de QTc et de dispersion du QTc plus élevés avant et après la HD. Ils étaient plus fréquemment hypertendus. La dépression du segment ST était significativement liée à l'arythmie ventriculaire.

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Introduction

According to the HEMO study, cardiac deaths account for 39.4% of all deaths in patients on chronic haemodialysis (HD). The main causes are ischaemic heart disease (61.5%), arrhythmia (17.2%) and congestive heart failure (10.5%). Nearly 25% of deaths were classed as sudden death, 89.4% of which were attributed to various cardiac causes and the rest to unknown causes [*1*]. Reported rates of sudden cardiac death range from 1.4% to 25%. The reasons for increased risk of sudden death are complex and multifactorial. They are related to acute myocardial infarction, haemorrhagic pericarditis, electrolyte disturbances and malignant ventricular tachyarrhythmia [*2*].

Cardiac arrhythmias are often observed after the start of HD, and can last up to 5 hours afterwards [*3*]. It is not clear if they are a consequence of dialysis or secondary to the haemodynamic and cardiovascular alterations often associated with chronic renal failure. Cardiac arrhythmia was found to be 2 times more frequent in patients under dialysis than predialysis or renal transplant patients, but the difference was not statistically significant [*4*]. The arrhythmogenicity depends on variable factors such as autonomic tone and ventricular anatomic structure and metabolism. Several causes (e.g. underlying ischaemic, rheumatic heart disease, uraemic pericarditis, cardiomyopathy, left atrial dilatation due to volume overload, hyperparathyroidism or the use of digitalin and beta-blockers) may contribute to the pathogenesis of arrhythmia [*5,6*]. Hypertension and myocardial dysfunction have also been implicated [*4*]. However, other important events induced during HD, such as rapid electrolyte fluctuations [*7*] and myocardial ischaemia [*8–10*], may contribute to their occurrence.

Corrected QT (QTc) interval and QTc dispersion (QTdc) can be used to predict serious arrhythmia [*11,12*]. Therefore, this study was carried out in order to: detect arrhythmia and ST-segment changes during HD in young patients with no concomitant cardiovascular disease using Holter ECG monitoring; determine the possible role of electrolytes and ischaemic changes that may occur during this procedure in arrhythmogenesis; and detect QTc interval and QTdc changes during HD and ascertain their relationship with arrhythmia.

Methods

Study sample

The study sample was drawn from patients in the renal dialysis unit of Assiut University Hospital from April to August 2005. All uraemic patients aged < 35 years on chronic HD (> 3 months; range 9–72 months) were eligible for inclusion if beta blockers and calcium channel blockers could be stopped 72 hours before the study without endangering the patient's life. Exclusion criteria included: having diabetes mellitus, underlying rheumatic or ischaemic heart disease, or uraemic pericarditis; ejection fraction < 60%, atrial fibrillation, bundle branch block, implanted permanent pacemaker, those unable to stop their medication; patients on digitalis or class I or III antiarrhythmic drugs; patients who did not give informed consent (~5) to the protocol and those in whom QTc interval could not be assessed in > 3 leads.

The study was approved by the ethical committee of the Faculty of Medicine at Assiut University and was conducted in accordance with the regulations of the Declaration of Helsinki.

Procedure

Beta blockers and calcium channel blockers were stopped 72 hours before the study if

feasible and without endangering the patient's life.

A 12-lead ECG was performed with the patient in a supine position after 5 min rest at paper speed 25 mm/s just before dialysis and within 15 minutes after dialysis. Maximum QTc interval and QTdc were measured manually from the 12-lead ECG as previously described [*13*] after being magnified on a Cannon photocopier (×3). A QTc interval > 440 ms and QTdc > 65 ms were considered abnormal. Intraobserver variability was assessed by repeated measurement of QTc and QTdc in a sample of 20 ECGs with a significant correlation ($r = 0.9$ for both). A calibrated 3-channel Holter recording system (Datrix XR-300, United States of America) was connected from the start to the end of the dialysis session.

The data were analysed for heart rate, arrhythmia, according to Lown's classification [*14*], and ischaemic changes (defined as > 1 mm of additional horizontal or downsloping ST segment depression, persisting for 80 ms after the J-point and maintained for > 1 minute) [*10*].

HD was performed using capillary artificial kidney (Fresenius 4008S, Germany) with bicarbonate-based HD parameters: 5 h/session, dialysate flow 500 mL/min, blood flow rate 300 mL/min and dialysate (all mmol/L) Na^+ 103, K^+ 2.0, Mg^{2+} 0.5, Ca^{2+} 1.75, Cl^+ 109.5, acetate 3.0.

In addition to serum urea and creatinine, serum electrolytes were measured at the start and at the end of dialysis with a spectrophotometer (Bayer RA-XT Chemistry Analyser with ion selective electrode, Germany) using Human Kits (Human Bio Chemical Co., USA); normal ranges were: Na^+ 135–155, K^+ 3.6–5.5, Ca^{2+} 2.1–2.6 and $Mg2^+$ 0.8–1 (all mmol/L). Echocardiography was done once in the post-dialysis day using a real-time ultrasound imaging system (Sonos 5000, Hewlett Packard, USA) with a phased array multifrequency 2–4 MHz transducer.

The standard echocardiographic measurements were done and averaged in 4 cardiac cycles. LVM and LVMI were calculated [*15*].

Statistical analysis

All data were analysed using *SPSS*, version 1. Means for continuous variables were compared using the paired sample *t*-test (before and after HD) and independent sample *t*-test (between groups). Values are represented as mean and standard deviation (SD). Differences and relationships in categorical variables were assessed using the chi-squared test with Fisher exact correction. $P < 0.05$ was considered statistically significant. All *P*-values were 2-tailed.

Intraobserver variabilities for QTc and QTdc were assessed using the Pearson correlation.

Results

A total of 48 uraemic patients (32 males and 16 females) were enrolled in the study; this was all uraemic patients on chronic HD in the renal dialysis unit of Assiut University Hospital during April–August 2005. All patients were aged < 35 [mean 30.1; SD = 2.6; range 20–34] years; 19 (40%) were hypertensive with mean left ventricular mass (LVM) 211.82 (SD = 90.9; range 128–521) g and mean left ventricular mass index (LVMI) 131.8 (SD = 80.2; range 66.3–303.9) g/m^2.

The changes in clinical, electrocardiographic and laboratory data by dialysis are shown in Table 1. Both systolic and diastolic blood pressure (BP) decreased significantly after dialysis. No serious hypotensive episode (systolic BP < 90 mmHg or decrease in systolic BP > 30 mmHg) occurred.

Table 1 **Changes in clinical, electrocardiographic and laboratory data before and after dialysis**

Parameter	Before dialysis		After dialysis	
	Mean	SD	Mean	SD
Systolic BP (mmHg) (range)	142 (124–170)	12.5	135*** (114–146)	10.1
Diastolic BP (mmHg) (range)	92.9 (92–114)	3.2	83.9** (70–88)	1.9
RR interval (ms)	631	41	622	32
Heart rate (beats/minute)	96.3	23.2	98.3	27.3
QTc (ms)	419.9	19.1	434.7***	20.2
QTdc (ms)	50.5	9.3	59.8***	8.3
Serum urea (mmol/L)	35.4	6.3	5.5***	2.2
Serum creatinine (μmol/L)	944	156	311***	75
Serum Na^+ level (mmol/L)	136.0	2.6	136.2	2.1
Serum K^+ level (mmol/L)	5.3	0.3	4.0***	1.1
Serum Ca^{2+} level (mg/dL)	2.00	0.15	2.57*	0.22
Serum Mg^{2+} level (mg/dL)	1.44	0.08	1.40	0.04

*P-*value < 0.05; **P-value < 0.01; ***P-value < 0.001.*
SD = standard deviation; BP = blood pressure; QTc = corrected QT interval; QTdc = corrected QT dispersion.

Holter ECG findings showed minor arrhythmia (Lown's grade I) in the form of unifocal, infrequent (< 30/h) premature beats in 29 patients (60%), atrial in 20 patients (42%) and ventricular in 18 patients (38%). Nine patients had both atrial and ventricular ectopic beats. All occurred during the last 2 hours of HD. Major arrhythmia was absent.

ST-segment depression diagnostic of myocardial ischaemia was observed in 28 (58%) patients during the last 2 hours of HD. None had previously-known objective signs of coronary artery disease and 20 (80%) had arrhythmia. Ten (36%) of these 28 patients experienced anginal pain while the rest were entirely asymptomatic. QTc, QTdc and serum electrolyte concentrations at the start and at the end of dialysis are shown in Table 1.

Patients who experienced arrhythmia during HD had lower post-dialysis K^+ concentrations, higher QTc and QTdc (both before and after HD), higher LVM and LVMI, all statistically significantly, than those who had no arrhythmia (Table 2). They were more frequently hypertensive. ST-segment depression was significantly related to ventricular arrhythmia, but not to atrial arrhythmia (Table 2).

Patients who had ST-segment depression were more frequently hypertensive, with a significantly higher LVM and LVMI compared to those without (Table 3). In addition, the post-dialysis K^+ concentration was significantly lower in those patients.

Discussion

Holter monitoring for 24 hours from the start of HD has demonstrated a high incidence of both atrial and ventricular arrhythmia [*3,10,5*]. In our study Holter monitoring during the period of HD showed no major arrhythmia. Only atrial and ventricular arrhythmias of Lown's grade I were recorded, all during in the last 2 hours of HD. The absence of major arrhythmia in this study is partly due to the selection criteria of our patients, which excluded patients > 35 years old, those with diabetes or underlying myocardial, pericardial or overt coronary artery

Table 2 **Clinical, electrocardiographic, echocardiographic and laboratory data in patients with and without atrial and ventricular arrhythmia**

Parameter	Atrial arrhythmia				Ventricular arrhythmia			
	Yes (*n* = 20)		No (28) (*n* = 20)		Yes (18) (*n* = 20)		No (30) (*n* = 20)	
	No.	%	No.	%	No.	%	No.	%
Male sex	15	75	17	61	11	61	21	70
Hypertension	12	60	7**	25	13	72	6**	20
ST-depression > 1 mm	13	65	15	54	15	83	13*	43
QTc >440 ms								
Before dialysis	7	35	1**	4	7	39	1**	3
After dialysis	15	75	3***	11	12	67	6*	20
QTdc >65 ms								
Before dialysis	9	45	2**	7	10	56	1***	3
After dialysis	7	35	2*	7	7	39	2**	7
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	29.6	1.5	30.5	3.1	30.5	1.9	29.8	2.9
Serum Na^+ (mmol/L)								
Before dialysis	136.2	3.0	135.8	2.3	136.3	2.6	135.8	2.6
After dialysis	136.5	2.4	136	1.9	136.0	2.1	136.6	2.1
Serum K^+ (mmol/L)								
Before dialysis	5.3	0.3	5.3	0.3	5.3	0.4	5.3	0.3
After dialysis	3.3	0.4	4.5***	1.1	3.1	0.3	4.5***	1.0
Serum Ca^{2+} (mg/dL)								
Before dialysis	2.80	0.20	1.97	0.12	2.02	0.15	1.95	0.15
After dialysis	2.62	0.22	2.52	0.25	2.64	0.22	2.52	0.22
Serum Mg^{2+} (mg/dL)								
Before dialysis	1.41	0.04	1.42	0.07	1.41	0.08	1.46	0.03
After dialysis	1.43	0.04	1.45	0.06	1.47	0.07	1.44	0.04
QTc (ms)								
Before dialysis	433	18	411**	14	430	20	414**	16
After dialysis	450	19	424***	13	443	26	430**	17
QTdc (ms)								
Before dialysis	53.0	6.4	45.1*	4.3	51.1	7.0	46.8*	5.8
After dialysis	62.0	7.6	56.7*	6.3	65.4	4.8	54.9***	5.5
LVM (g)	256.9	110.0	180.0**	57.2	275.0	105.8	173.9***	53.5
LVMI (g/m^2)	178.0	97.5	98.8***	42.4	190.8	90.5	96.4***	46.4

*P-*value <0.05;* **P-*value < 0.01;* ***P-*value < 0.001.*
P-*value is for the difference between groups with and without arrhythmia of similar type.*
SD = standard deviation.
QTc = corrected QT interval.
QTdc = corrected QT dispersion.
LVM = left ventricular mass.
LVMI = left ventricular mass index.

Table 3 **Clinical, echocardiographic and laboratory data for dialysis patients with and without ST-segment depression**

Parameter	ST-depression (*n* = 28)		No ST-depression (*n* = 20)	
	Mean	SD	Mean	SD
Age (years)	30.1	2.2	30.1	3.1
Serum Na+ (mmol/L)				
Before dialysis	136.2	2.5	135.7	2.6
After dialysis	135.9	2.2	136.7	2.0
Serum K+ (mmol/L)				
Before dialysis	5.3	0.4	5.3	0.3
After dialysis	3.6	0.9	4.5	1.1**
Serum Ca^{2+} (mg/dL)				
Before dialysis	1.97	0.12	2.00	0.17
After dialysis	2.59	0.22	2.57	0.22
Serum Mg^{2+} (mg/dL)				
Before dialysis	1.46	0.09	1.41	0.07
After dialysis	1.45	0.07	1.42	0.06
LVM (g)	244.2	101.9	177.4***	44.2
LVMI (g/m^2)	162.6	90.9	88.6*	28.3
Male sex [No. (%)]	20 (71%)		12 (60%)	
Hypertension [No. (%)]	15 (54%)		4 (20%)*	

*P-*value* < 0.05; **P-*value* < 0.01; ***P-*value* < 0.001.
SD = standard deviation.
LVM = left ventricular mass; LVMI = left ventricular mass index.

diseases. All of these have been found to be associated with increased incidence of major arrhythmias during HD [*3,5,9*].

It has been suggested that both symptomatic and silent ischaemia may occur frequently during HD [*8,10,16*] because HD simultaneously reduces coronary artery oxygen delivery while increasing myocardial oxygen demand. Reduced coronary oxygen delivery is attributed to hypotension secondary to acute intravascular volume depletion as a result of ultrafiltration [*8,16*]. The increased myocardial oxygen consumption is due to increased myocardial contractility and LVH [*17*].

In our study, coronary angiography was not performed to detect the presence of coronary artery disease. This is for ethical reasons in performing such an invasive manoeuvre on young uraemic patients without evident cardiac co-morbidity and with low expected possibility of coronary artery disease.

Holter was used for the detection of ST depression as a marker of myocardial ischaemia. This ST depression reflects a true coronary artery disease, a relative ischaemia secondary to left ventricular hypertrophy and/or hypertension, or ST shift secondary to electrolyte disturbances. We found ST-segment depression in 58% of patients by the end of HD, 36% of whom were symptomatic, suggesting true ischaemia (coronary artery disease or relative ischaemia) as the cause of ST-segment depression.

There was not a single hypotensive episode in this study, thus hypotension was excluded as a cause of ST depression. In symptomatic patients, detection of ST-segment depression during HD has been found to be useful in diagnosing coronary

artery disease and is considered an important prognostic indicator of subsequent cardiac events [*16*].

In a recent report, silent myocardial ischaemia, detected by Holter in asymptomatic patients, was found to predispose to clinically significant ventricular arrhythmia during and after HD [*8*]. This was not correlated with epicardial coronary artery disease. Coronary artery spasm during HD has been suggested as the possible cause of silent ischaemia in these patients. In our study, the possibility of coronary artery disease, though low, especially in asymptomatic patients, cannot be excluded considering the high prevalence of documented coronary artery disease (up to 40%) in uraemic patients [*1*] and the low sensitivity of clinical symptoms for diagnosis of ischaemia in uraemia [*10,16*]. We found ST depression to be associated with hypertension and higher LVM and LVMI. This means that this ischaemia is likely to be, at least in part, a relative ischaemia rather than a true coronary artery disease.

On the other hand, 46% of our patients with ST depression were not hypertensive and 20% without ST depression were hypertensive. This means that hypertension is just 1 cause of, or a contributing factor to, the ST depression found at the end of dialysis. Also, the association of ST depression with a lower post-dialysis K^+ concentration, which was similarly found in a previous report [*8*], suggests a possible role of electrolytes, especially in people who were not hypertensive. Against this explanation is the absence of other ECG criteria of hypokalaemia (flattening of the T-wave or prominence of the U-wave).

Factors contributing to arrhythmogenesis

Patients who experienced either atrial or ventricular ectopics in our study had a lower post-dialysis K^+ concentration. They were more frequently hypertensive and had higher LVM and LVMI. Also, patients with ventricular ectopics had a higher incidence of ST depression by the end of dialysis compared to those without ectopics. This means that dialysis-associated arrhythmia occurring in young non-diabetic patients without overt coronary artery disease is related to decreased serum K^+ level; LVH associated with hypertension; and occurrence of myocardial ischaemia.

Previous reports have suggested the role of both electrolyte disturbances [*7*] and hypertension [*4*] in the genesis of both atrial and ventricular arrhythmia in uraemic patients. Silent ischaemia has also been suggested to play a role in the genesis of ventricular arrhythmia as has the presence of LVH [*8,10,18*]. However, these studies included a heterogeneous group of patients with underlying co-morbidities that can themselves cause arrhythmia.

It has been suggested that transmembrane ion transport is abnormal in chronic renal failure, which predisposes the cells to K^+ depletion, which in turn might impair the correction of intracellular acidosis during HD. This intracellular acidosis in myocardial cells in the face of a relative correction of extracellular pH by HD may contribute to arrhythmogenesis [*7*]. A second mechanism is hypokalaemia, which may occur at the end of dialysis due to rapid correction of acidosis, which leads to major transcompartmental shift of K^+ at a rate exceeding the capacity of K^+ transfer across the dialysis membrane to compensate [*19*]. Accordingly, consideration should be given to using a high K^+ dialysate in such patients and to monitoring the K^+ level during dialysis. The interaction between serum K+ and dialysate K^+ is a third mechanism in the genesis of arrhythmia because dialysis induces rapid decrease in serum K^+, especially during the

first 2 hours [*20*]. The changes in extracellular K^+ level result in decreased transmembrane electrical potential in the myocardial cells and decreased speed of myocardial electrical conduction [*7*].

In our study, Ca^{2+} level increased significantly as a consequence of HD, however, the increase was not related to arrhythmogenesis. This is probably because, despite being statistically significant, the magnitude of the increase was small, and still within the normal range. This can be explained by the Ca^{2+} concentration in the dialysate used (1.75 mmol/L). The increased Ca^{2+} level during HD is attributed to positive flux of Ca^{2+} from the dialysate as well as increased protein binding of Ca^{2+} as a result of correction of acidosis during HD [*21*].

The mechanism of ventricular arrhythmia in patients with LVH is unclear. Triggered activity due to early and/or late after depolarization is one mechanism [*17*]. A second mechanism is re-entry secondary to collagen deposition and ventricular fibrosis associated with LVH, which can cause unidirectional block and re-entrant circuits, together with the associated prolonged action potential duration in LVH [*17*].

Repolarization abnormalities in HD

Prolonged QTc and QTdc have been indicated as predictors of sudden death in a variety of clinical conditions [*22*]. Several reports have demonstrated increased QTc from HD [*12,13*]. The effect of dialysis on QTdc is, however, controversial. HD increased QTdc in most of the reports [*21,23–26*]. Peritoneal dialysis was also found to increase QTdc [*27*]. There were no significant differences from HD in one report [*27*] and level was lower than HD in another [*25*].

All the above studies were small, with a maximum of 40 patients, and had heterogenous groups of patients with underlying co-morbidities that can affect QTdc, except those of Wu et al. (101 patients) [*27*] and Covic et al. (homogeneous group of 68 patients) [*13*].

Our study used nearly the same inclusion criteria as Covic et al. but in younger patients (< 35 years). Despite the increased mean QTc by HD, the mean value both before, 419.9 (SD 19.1) ms] and after [434 (SD 20.2) ms] HD was within the normal range and relatively low compared to data from Morris et al. [474.4 (SD 32.6) ms before HD and 489.7 (SD 39.7) after] [*28*], but close to those of Covic et al. [430 (SD 27) ms before HD and 443 (SD 27) after]. QTdc in our data was also low [50.5 (SD 9.3) ms before HD and 59.5 (SD 8.3) after] compared to Morris et al. [*28*] [74.1 (SD 26.0) ms before HD and 86.7 (SD 29.6) after], but comparable to that of Covic et al. [*13*] [35 (SD 16) ms before HD and 40 (SD 24) after]. This may be attributed to differences in patient selection criteria.

The mechanism of QTdc prolongation in patients with end-stage renal disease is not fully understood. It is partly due to autonomic failure caused by autonomic neuropathy. Other factors that can affect it include associated co-morbidities such as congestive heart failure, LVH, diabetes, ischaemic heart disease and impaired Mg^{2+}, K^+, Ca^{2+} and/or phosphate metabolism in uraemic patients [*22*]. The role of electrolytes is still controversial. It has been attributed to iron body stores [*27*], changes in Ca^{2+} concentration [*21,25*], cell associated Mg^{2+} in the mononuclear cells in the peripheral blood [*23*] and K^+ removal during dialysis [*26*].

Most of the published reports have shown either increased incidence of arrhythmia or increased repolarization abnormalities in HD patients, and the causal relationship between them is mainly speculation. One report linked prolonged QTc and complex arrhythmia during HD [*12*]. Also, a

retrospective report on patients under HD confirmed the prognostic value of QTdc for identifying dialysis patients at increased risk of overall and complex arrhythmia [*11*]. In concurrence with these data, our study showed a longer QTc and QTdc in patients who experienced arrhythmia (atrial or ventricular) both before and after HD.

Conclusions

Young uraemic patients on regular HD, without associated co-morbidities, are susceptible to arrhythmia, however, the risk of major arrhythmia is minimal or absent. Such arrhythmia may be attributed to hypokalaemia and/or dialysis-associated myocardial ischaemia in addition to left ventricular hypertrophy. Repolarization abnormalities, detected non-invasively may be important pathogenic mechanisms for such arrhythmia.

References

1. Cheung AK et al. Cardiac diseases in maintenance hemodialysis patients: results of the HEMO study. *Kidney international*, 2004, 65:2380–9.
2. Lorincz I et al. QT dispersion in patients with end-stage renal failure and during haemodialysis. *Journal of the American Society of Nephrology*, 1999, 10:1297–302.
3. Abe S et al. Electrocardiographic abnormalities in patients receiving haemodialysis. *American heart journal*, 1996, 131:1137–44.
4. De Lima JJ et al. Blood pressure and the risk of complex arrhythmia in renal insufficiency, haemodialysis, and renal transplant patients. *American journal of hypertension*, 1999, 12:204–8.
5. Ansari N, Manis T, Feinfeld DA. Symptomatic atrial arrhythmias in haemodialysis patients. *Renal failure*, 2001, 23:71–6.
6. Bahrle S, Schols W. Torsade de pointes in haemodialysis patients. *Nephrology, dialysis, transplantation*, 1996, 11(6):944–6.
7. Redaelli B. Hydroelectrolytic equilibrium change in dialysis. *Journal of nephrology*, 2001, 14:S7–11.
8. Mohi-ud-din K, et al. Silent myocardial ischaemia and high-grade ventricular arrhythmias in patients on maintenance haemodialysis. *Renal failure*, 2005, 27:171–5.
9. Kitano Y et al. Severe coronary stenosis is an important factor for induction and lengthy persistence of ventricular arrhythmias during and after haemodialysis. *American journal of kidney disease*, 2004, 44:328–36.
10. Narula AS et al. Cardiac arrhythmias and silent myocardial ischaemia during haemodialysis. *Renal failure*, 2000, 22:355–68.
11. Beaubien ER et al. Value of corrected QT interval dispersion in identifying patients initiating dialysis at increased risk of total and cardiovascular mortality. *American journal of kidney disease*, 2002, 39(4):834–42.
12. Suzuki R, et al. QT interval prolongation in the patients receiving maintenance haemodialysis. *Clinical nephrology*, 1998, 49:240–4.
13. Covic A et al. Haemodialysis increases QTc interval but not QTc dispersion in ESRD patients without manifest cardiac disease. *Nephrology, dialysis, transplantation*, 2002, 17:2170–7.

14. Lown B, Wolf M. Approaches to sudden death from coronary heart disease. *Circulation*, 1971, 44:130.

15. Foley RN et al. The prognostic importance of left ventricular geometry in uraemic cardiomyopathy. *Journal of the American Society of Nephrology*, 1995, 5(12):2024–31.

16. Nakamura S et al. Prediction of coronary artery disease and cardiac events using electrocardiographic changes during haemodialysis. *American journal of kidney disease*, 2000, 36:592–9.

17. Hennersdorf MG, Strauer BE. Arterial hypertension and cardiac arrhythmias. *Journal of hypertension*, 2001, 19:167–77.

18. Renke M et al. Interrelationship between cardiac structure and function and incidence of arrhythmia in peritoneal dialysis patients. *International journal of artificial organs*, 2001, 24(6):374–9.

19. Wiegand CF et al. Severe hypokalaemia induced by haemodialysis. *Archives of internal medicine*, 1981, 141(2):167–70.

20. Ramirez G, Brueggemyer CD, Newton JL. Cardiac arrhythmia in haemodialysis in chronic renal failure patients. *Nephron*, 1984, 36:212–21.

21. Nappi SE et al. QTc dispersion increases during haemodialysis with low-calcium dialysate. *Kidney international*, 2000, 57:2117–22.

22. Wu VC, Lin LY, Wu KD. QT interval dispersion in dialysis patients. *Nephrology*, 2005, 10:109–12.

23. Averbukh Z et al. Cell-associated magnesium and QT dispersion in haemodialysis patients. *American journal of kidney disease*, 2003, 41:196–202.

24. Kantarci G et al. QT dispersion in haemodialysis and CAPD patients. *Nephron*, 2002, 91:739–41.

25. Yildiz A et al. QT dispersion and signal-averaged electrocardiogram in haemodialysis and CAPD patients. *Peritoneal dialysis international*, 2001, 21:186–92.

26. Cupisti A et al. Potassium removal increases the QTc interval dispersion during haemodialysis. *Nephron*, 1999, 82:122–6.

27. Wu VC et al. The effect of iron stores on corrected QT dispersion in patients undergoing peritoneal dialysis. *American journal of kidney disease*, 2004, 44:720–8.

28. Morris SW et al. QT dispersion before and after haemodialysis. *Journal of the American Society of Nephrology*, 1999, 10:160–3.