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CLINICAL STUDY

The Effect of Different Dialysate Magnesium Concentrations on QTc Dispersion in Hemodialysis Patients

Farsad Afshinnia[1], Hardik Doshi[2] and Panduranga S. Rao[1]

[1]*Division of Nephrology, Department of Internal Medicine, University of Michigan Health System, Ann Arbor, MI, USA;*
[2]*Department of Internal Medicine, University of Iowa, Iowa City, IA, USA*

Abstract

Background: Electrolyte changes during dialysis affect corrected QT (QTc) and QTc dispersion (QTcd), a surrogate marker of arrhythmogenicity. The impact of magnesium on QTcd is not clear. *Methods*: Twenty-two stable patients on maintenance hemodialysis were enrolled in this study. Each underwent two consecutive hemodialysis sessions at least 2 days apart, the first against normal magnesium dialysate (with magnesium at 1.8 mg/dL) followed by a low magnesium dialysate (with magnesium at 0.6 mg/dL). Pre- and post-dialysis weights, blood pressure, electrolytes, and 12-lead surface EKG were recorded. The QT interval and the QTcd were calculated before and after dialysis in both sessions. *Results*: Of 22 patients, 16 were female. The mean age ± SD was 53.7 ± 18.0 years. The mean change of QTcd (pre- vs. post-dialysis) was 9.5 ms ($p = 0.120$) and 9.3 ms ($p = 0.145$) in low and normal magnesium groups, respectively. Using univariate analysis, there was a statistically significant decrease in the mean blood pressure, weight, potassium, magnesium, and QTc interval post-dialysis (compared to pre-dialysis) in both groups ($p \leq 0.049$). Post-dialysis concentrations of sodium and calcium were unchanged (compared to pre-dialysis) but bicarbonate increased with both dialysate groups ($p < 0.001$). The mean change of QTcd was not significant pre- versus post-dialysis by univariate analysis in either group. Multiple linear regression analysis adjusting for pertinent factors did not change the results in either of the two groups. *Conclusion*: Using a low magnesium dialysate bath in hemodynamically stable hemodialysis patients without preexisting advanced cardiac disease does not significantly impact QTcd.

Keywords: end-stage renal disease, hemodialysis, QTc dispersion, magnesium, arrhythmia

INTRODUCTION

The field of hemodialysis has witnessed major advances in technology and dialysis practice in the last decade. This has included newer machines with ultrafiltration control, sodium and ultrafiltration profiling, and a clearer understanding of the concept of adequacy of dialysis. However, in spite of these advances the mortality of patients on hemodialysis in the United States has remained high at about 20% annually. The principal cause of death in these patients is cardiovascular. The incidence of sudden death in hemodialysis patients ranges from 1.4% to 25%.[1] Patients on dialysis have a higher incidence of arrhythmias during and after dialysis. This may not be entirely unexpected in view of several factors, including presence of cardiac ischemia, left ventricular hypertrophy, autonomic neuropathy, and rapid changes of intra- and extracellular electrolytes.[2] Some of the electrolyte shifts may be inevitable, especially potassium shifts.

Magnesium levels are usually elevated in dialysis patients.[3–6] In a recent study, low cell-associated magnesium achieved with a low magnesium intake was associated with a significant reduction in corrected QT dispersion (QTcd), a surrogate marker of arrythmogenicity.[7] Therefore, change of serum magnesium level by manipulation of dialysate magnesium concentration may have alleviating or aggravating effect on the susceptibility to arrhythmogenicity. Although there are reports of dialysis against low magnesium,[8–10] to our knowledge there is no study to evaluate the effect of different dialysate magnesium concentrations on QTcd. This study is aimed to compare the changes of QTc and

Address correspondence to Panduranga S. Rao, Division of Nephrology, Department of Internal Medicine, University of Michigan Health System, 102 Observatory Road, Simpson Memorial Building, Ann Arbor, MI 48109, USA. Tel.: 734-615-3994; Fax: 734-615-4887; E-mail: spandu@umich.edu

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QTcd from pre- to post-dialysis in low (0.6 mg/dL) and normal (1.8 mg/dL) magnesium dialysate concentrations. We also aimed to identify the variables that would be independently associated with change in QTcd.

METHODS

This study is a case crossover design of 22 patients with end-stage renal disease (ESRD) who were on hemodialysis for a median of 37 months (interquartile range of 17–82.5 months). The patients were recruited from outpatient hemodialysis centers of the University of Michigan. The study was conducted at the University of Michigan Health System from January to June 2006. The study protocol was approved by the institutional review board. All the participants signed informed consent prior to their participation. Inclusion criteria were patients over 18 years on chronic hemodialysis for at least 3 months at the outpatient hemodialysis unit of the university. Exclusion criteria were patients with acute renal failure needing renal replacement therapy, history of arrhythmias, advanced cardiovascular disorders, and recent electrophysiological evaluation or having pacemakers. Advanced cardiovascular disorders are defined as decompensated congestive heart failure with New York Heart Association class III or IV, history of coronary artery disease defined by acute coronary syndrome, critical stenosis of coronary arteries by angiogram, and significant valvular heart disease demonstrated by either echocardiography or ventriculography.

For each patient the history and physical examination were obtained and detailed inventory of current medications was recorded. Dialysis sessions were on the second and third dialysis days of the week. Fresenius dialysis machines (Fresenius Medical Corporation, Waltham, MA, USA), using polysulphone F-200 NR (surface area 2.0 square meter, ultrafiltration coefficient 62 mL/h/mmHg) dialyzer were used for an average of 3.5 h per session. Patients underwent two consecutive dialysis sessions according to the study protocol at least 2 days apart. The first session was against standard magnesium dialysate with a concentration of 1.8 mg/dL, and the second session was against a low magnesium dialysate of 0.6 mg/dL. The dialysate solutions were otherwise identical and contained 138 mEq/L sodium chloride, 2.0 mEq/L potassium, 2.5 mEq/L calcium, 110 mEq/L chloride, and 33 mEq/L bicarbonate. All participants had measurement of their weight in standing position on the same weighing scale throughout the study immediately before and after the dialysis session. After pre-dialysis recording of their weight, blood pressure was measured at sitting position in the arm with no dialysis access, with their arm at heart level, and after at least 10 min of rest. A 12-lead surface EKG at a paper speed of 50 mm/s was obtained before initiation of dialysis. Upon cannulation of the dialysis access, 10 mL of blood was drawn. After the start of the session, the patients were under close monitoring and observation, including measurement of their blood pressure and heart rate according to established protocol. At the end of each dialysis session with the blood pump running at 50 mL/min, patients had a second sample of blood draw for a repeat metabolic panel measurement. The second 12-lead surface EKG was obtained immediately after patients were completely off the machine. QT interval was defined as the interval between the start of the Q wave and the end of the T wave. QTc interval was calculated as $QT/(RR)^{0.5}$. QTcd is defined as the difference between the maximum and the minimum QTc intervals in the 12-lead EKG. All the EKG studies were read and abstracted by the same observer.

Statistical Analysis

To compare the mean of continuous variables before and after dialysis, Student's *t*-test for paired samples was applied. Bivariable Pearson correlation coefficient was used to investigate the relationship of changes in each one of the study variables during dialysis with that of QTcd separately. Multiple linear regression analysis was applied to identify the variables independently associated with variability of QTcd. Less than 15 ms change in QTc or QTcd is considered to be clinically a nonsignificant change. A sample size of 18 was required to detect a minimum difference of 15 ms with 90% power at an alpha level of 0.05. At the end, 22 patients were selected to account for possible dropouts.

RESULTS

Of 22 study patients, there were 16 females (72.7%) and 6 males (27.3%). Nine patients (40.9%) were African Americans and 13 patients (59.1%) were Caucasians. The mean (SD) age was 53.7 (18.0) years. Etiology of ESRD was diabetes in eight patients; hypertension, focal segmental glomerulosclerosis, and systemic lupus erythematosus each in three patients; and polycystic kidney disease, congenital renal dysplasia, Alport

Table 1. Baseline characteristics of the study patients.

Variables	Study subjects
Age (years)	53.7 ± 18.0
Male (%)	6 (27.3)
Black race (%)	9 (40.9)
Hb (low Mg session)	12.0 ± 1.0
Hb (normal Mg session)	12.1 ± 1.0
Kt/V (low Mg session)	1.5 ± 0.2
Kt/V (normal Mg session)	1.5 ± 0.3
Antihypertensive medications	
Beta-blockers (%)	15 (68.2)
Loop diuretics (%)	4 (18.2)
Calcium channel blockers (%)	4 (18.2)
Alpha-blocker (%)	1 (4.5)
Comorbid conditions	
Hypertension (%)	21 (95.5)
Diabetes (%)	9 (40.9)
Coronary artery disease (%)	4 (18.2)
Congestive heart failure (%)	3 (13.6)

syndrome, membranoproliferative glomerulonephritis, and unknown kidney disease each in one patient. The class of antihypertensive medications and the comorbid conditions are listed in Table 1. Pre-dialysis hemoglobin in both low and normal magnesium sessions was stable and unchanged as was mean single-pool equilibrated achieved Kt/V (Table 1). Table 2 shows that in both low and normal magnesium dialysate groups, there was a significant decrease in body weight, systolic and diastolic blood pressure post-dialysis versus pre-dialysis ($p < 0.001$), as was serum potassium and magnesium ($p < 0.001$). Serum sodium and calcium were not changed, but serum bicarbonate increased significantly ($p < 0.001$). There was a significant increase in the mean QTc in both groups ($p \leq 0.049$). After dialysis, compared to pre-dialysis, the QTcd decreased in low magnesium bath group and increased in the normal magnesium bath group, but did not achieve statistical significance in either group. QTcd was slightly lower prior to dialysis in the normal magnesium group as compared to the low magnesium group. It is likely to be the result of within-patient variability without any apparent clinical or statistical significance.

To investigate the variables associated with change of QTcd in its entire range, bivariate Pearson correlation coefficient was applied. Accordingly, no other covariate including age, change of weight, change of blood pressure during dialysis, and/or changes of electrolytes including sodium, potassium, calcium, magnesium, and bicarbonate was associated with change of QTc or QTcd with univariate approach (Table 3). There was no relationship between the use of beta-blockers and the change of QTc or QTcd.

DISCUSSION

In this study, we showed that there was a significant prolongation of QTc after dialysis with both normal and low magnesium dialysate baths. Change of QTcd, however, was not statistically different in either of the two magnesium concentration baths. It was not associated with age, change in electrolytes, and change in weight

Table 2. Changes of blood pressure, weight, electrolytes, and QT intervals before and after hemodialysis in low and normal dialysate magnesium concentrations.

	Low magnesium bath			Normal magnesium bath		
Variables	Before Mean ± SD	After Mean ± SD	*p*-Value	Before Mean ± SD	After Mean ± SD	*p*-Value
SBP (mmHg)	147.7 ± 21.8	125.0 ± 18.8	<0.001	143.8 ± 12.8	123.8 ± 13.4	<0.001
DBP (mmHg)	76.6 ± 10.0	68.7 ± 11.1	<0.001	76.1 ± 10.6	65.9 ± 11.0	<0.001
Heart rate (per min)	71.1 ± 9.0	82.3 ± 15.7	0.002	71.4 ± 8.8	82.8 ± 16.0	0.002
Weight (kg)	78.2 ± 14.3	76.0 ± 14.1	<0.001	78.4 ± 14.3	74.2 ± 11.7	<0.001
Na (mmol/L)	138.9 ± 2.7	139.5 ± 2.1	0.234	138.4 ± 2.3	139.2 ± 1.6	0.143
K (mmol/L)	4.8 ± 0.5	3.5 ± 0.4	<0.001	4.9 ± 0.8	3.4 ± 0.3	<0.001
Mg (mg/dL)	1.8 ± 0.2	1.2 ± 0.1	<0.001	1.8 ± 0.2	1.6 ± 0.1	<0.001
iCa (mEq/L)	2.4 ± 0.2	2.5 ± 0.2	0.117	2.5 ± 0.2	2.5 ± 0.1	0.134
HCO_3 (mmol/L)	23.7 ± 3.3	26.7 ± 2.3	<0.001	22.7 ± 3.0	28.3 ± 2.4	<0.001
QTcd (ms)	76.3 ± 31.4	67.0 ± 24.9	0.145	65.9 ± 21.0	75.4 ± 21.7	0.120
QTc (ms)	444.2 ± 26.3	460.9 ± 26.8	<0.001	446.0 ± 32.9	460.0 ± 27.3	0.049

Note: SBP, systolic blood pressure; DBP, diastolic blood pressure; Na, sodium; K, potassium; Mg, magnesium; iCa, ionized serum calcium; HCO_3, bicarbonate; QTcd, corrected QT dispersion; QTc, corrected QT interval.

Table 3. Bivariate correlation coefficient of change in QTc and QTc dispersion with age and changes of blood pressure and electrolytes before and after dialysis in low and normal magnesium dialysate concentrations.

	Low magnesium bath				Normal magnesium bath			
	ΔQTcd		ΔQTc		ΔQTcd		ΔQTc	
Variables	*r*	*p*-Value	*r*	*p*-Value	*r*	*p*-Value	*r*	*p*-Value
Age (years)	0.07	0.75	0.28	0.20	0.12	0.60	0.01	0.97
ΔSBP (mmHg)	0.22	0.33	0.05	0.10	−0.25	0.26	0.31	0.17
ΔDBP (mmHg)	0.04	0.85	0.17	0.46	−0.26	0.24	0.38	0.08
ΔWeight (kg)	−0.12	0.59	−0.12	0.60	0.29	0.21	0.26	0.27
ΔNa (mmol/L)	0.34	0.13	0.02	0.94	0.15	0.49	0.01	0.95
ΔK (mmol/L)	0.03	0.89	0.25	0.26	−0.16	0.49	0.15	0.50
ΔiCa (mEq/L)	−0.08	0.74	0.15	0.52	0.05	0.82	−0.26	0.23
ΔMg (mg/dL)	−0.12	0.59	0.20	0.38	−0.14	0.55	0.23	0.31
ΔHCO_3 (mmol/L)	−0.08	0.72	0.17	0.17	0.42	0.06	−0.33	0.15
Beta-blocker use[a]	−0.05	0.84	0.02	0.92	−0.03	0.89	−0.34	0.08

Notes: Δ is the product of before minus after dialysis; SBP, systolic blood pressure; DBP, diastolic blood pressure; Na, sodium; K, potassium; iCa, ionized serum calcium; Mg, magnesium; HCO_3, bicarbonate.
[a]Correlation coefficient for beta-blocker is Spearman correlation coefficient.

or blood pressure during dialysis using either univariate or multivariable analysis.

Change of QTcd is commonly reported in dialysis patients.[2,11–14] One study showed that it was even higher in hemodialysis patients as compared to patients on peritoneal dialysis.[13] Rapid changes in electrolyte plasma concentrations particularly in the presence of subclinical ischemia, left ventricular hypertrophy, and congestive heart failure are the likely explanation of prolonged QTc interval and QTcd in dialysis patients.[15–17] Increase in QTcd is a reflection of nonhomogeneous recovery of ventricular excitability, which may put patients at a significantly higher risk of reentrant arrhythmias and sudden death after dialysis.[17,18] In another study, Beaubien et al. confirmed the prognostic value of prolongation of QTcd and the significantly higher total and cardiovascular mortality risk associated with it in a cohort of 147 dialysis patients.[19] Accordingly, a 50 ms difference in QTcd was associated with 1.53 times increase in total mortality. The magnitude of decrease in QTcd observed in our study with the low magnesium group is relatively small, is statistically not significant, and is unlikely to be associated with significant change in risk. Although we observed a statistically significant increase in QTc, the lack of significant change in the mean QTcd is likely a reflection of a relative cardiovascular stability and low prevalence of coexisting coronary artery disease (CAD) and congestive heart failure (CHF) in our study patients. This is consistent with Covic's findings who reported no significant change in QTcd in the absence of coexisting cardiac disease.[15] The immediate hours after termination of dialysis is the time for volume and electrolyte equilibration that may be associated with increased risk of a hyperadrenergic state. Locsey et al. have shown that in unstable dialysis patients there is a higher frequency of arrhythmias and ST depression using ambulatory 24-h blood pressure monitoring.[20] Other studies using Holter monitoring recommend a similar higher frequency of arrhythmias in unstable patients.[21,22] In our study, however, we have only obtained EKG immediately after dialysis and did not have any repeat EKG within the next few hours. Given a higher frequency of arrhythmias seen mainly in unstable patients and a relative stability of enrolled patients in this study, the yield of achieving a different result by repeat EKG in the subsequent hours would be expected to be low. A similar increase in QTc in both dialysis sessions also suggests that the increase has been independent of dialysate magnesium concentration.

Magnesium level is generally higher in dialysis patients as a result of its normal intake with decreased excretion.[4] The consequences of hypermagnesemia range from no symptoms with plasma level <1.5 mmol/L to somnolence, loss of deep tendon reflexes, hypocalcemia, and hypotension with levels between 3 and 5 mmol/L, and finally to apnea, complete heart block, and cardiac arrest with levels >5 mmol/L.[4] The effect of low magnesium dialysate bath on changes of QTcd has not been well studied. However, studies that have used low magnesium bath have reported a higher rate of muscle cramps,[9] and hypotension,[8,23] likely secondary to decreased myocardial contractility. None have, however, examined other important parameters such as QTcd. In our study, a significant decrease in serum magnesium concentration was observed with both normal and low magnesium dialysate baths. However, change in serum magnesium was not associated with change in QTcd. Changes in other electrolytes including decrease in potassium and increase in bicarbonate after dialysis are expected findings of our trial and can be explained by the electrolyte gradients between the blood and the dialysate. Similarly decrease in weight and blood pressure after dialysis is partially explained by ultrafiltration during dialysis.

Prolongation of QTcd in association with high serum calcium and low potassium is reported in a few studies.[2,24] On the other hand, Nappi et al. have reported increase in QTcd with low calcium dialysate bath, when change of intradialytic serum magnesium was clinically nonsignificant.[25] In two other studies, Howse and Yildiz did not find any correlation between change in QTc or QTcd with changes in calcium, magnesium, potassium, and bicarbonate and change in subjects' weight, all of which changed during dialysis.[11,13] This is consistent with our study in which the change in ionized serum calcium on average was not significant after dialysis. The change of ionized calcium at individual level was not correlated with the change of QTcd either. However, in our study pre-dialysis range of serum magnesium level was within normal limit. Therefore, the baseline pre-dialysis level of serum electrolytes and their concentrations in dialysate bath are likely the determinant of the direction and overall magnitude of the change in QTcd in a given patient. Blockage of late sodium channels reduces transmural dispersion of repolarization by abbreviating the duration of action potential of the myocardial cells and suppression of development of early afterdepolarization.[26,27] However, further research is needed to show whether manipulation of late sodium channel would translate to decrease of QTcd and improved outcome in high-risk dialysis patients.

To our knowledge, this study is the first to evaluate the effect of low magnesium dialysate baths on QTcd. This study has several limitations. First, it has a small sample size, and observations were limited to one dialysis session per magnesium concentration which may limit the generalizability of the results. Therefore, a larger study with more frequent dialysis sessions against different dialysate concentrations may help to confirm these findings. Second, the setting in this study is outpatient dialysis patients, and therefore the results may not be generalized to the inpatient clinical setting. Third, given the small sample size, the study was limited by adjustment for a limited number of covariates. Fourth,

the pre-dialysis ranges of electrolytes were within normal limit, and therefore the results of this study should be interpreted with caution and not be extrapolated to extremes of electrolyte abnormalities beyond the range of observation in this study. Finally, the patients in this study were relatively stable with a low prevalence of CAD, CHF, and no prior history of cardiac arrhythmia, limiting its generalizability.

In conclusion, in stable hemodialysis patients without advanced cardiovascular diseases, including CAD, CHF, and preexisting arrhythmias, the use of low magnesium concentration dialysate does not significantly impact the QTcd. Future research may incorporate similar protocol with different dialysate magnesium concentration baths in high-risk hemodialysis patient population and to investigate strategies to minimize QTcd in such patients, including but not limited to antiarrhythmic agents.

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REFERENCES

[1] Kimura K, Tabei K, Asano Y, Hosoda S. Cardiac arrhythmias in hemodialysis patients. A study of incidence and contributory factors. *Nephron.* 1989;53:201–207.

[2] Yetkin E, Ileri M, Tandogan I, et al. Increased QT interval dispersion after hemodialysis: Role of peridialytic electrolyte gradients. *Angiology.* 2000;51:499–504.

[3] Huijgen HJ, Sanders R, van Olden RW, Klous MG, Gaffar FR, Sanders GT. Intracellular and extracellular blood magnesium fractions in hemodialysis patients; is the ionized fraction a measure of magnesium excess? *Clin Chem*. 1998;44:639–648.

[4] Navarro-Gonzalez JF. Magnesium in dialysis patients: Serum levels and clinical implications. *Clin Nephrol.* 1998;49:373–378.

[5] Paskalev E, Genova M. Free magnesium in patients on regular dialysis treatment. *Nephron.* 1999;81:356–357.

[6] Pedrozzi NE, Truttmann AC, Faraone R, et al. Circulating ionized and total magnesium in end-stage kidney disease. *Nephron.* 1998;79:288–292.

[7] Averbukh Z, Rosenberg R, Galperin E, et al. Cell-associated magnesium and QT dispersion in hemodialysis patients. *Am J Kidney Dis.* 2003;41:196–202.

[8] Elsharkawy MM, Youssef AM, Zayoon MY. Intradialytic changes of serum magnesium and their relation to hypotensive episodes in hemodialysis patients on different dialysates. *Hemodial Int.* 2006;10(Suppl. 2):S16–S23.

[9] Kelber J, Slatopolsky E, Delmez JA. Acute effects of different concentrations of dialysate magnesium during high-efficiency dialysis. *Am J Kidney Dis.* 1994;24:453–460.

[10] Kyriazis J, Pikounis V, Smirnioudis N. Use of the QTc interval and QTc dispersion in patients on hemodialysis: Assessment of reproducibility. *Nephrol Dial Transplant.* 2004;19:516–517.

[11] Howse M, Sastry S, Bell GM. Changes in the corrected QT interval and corrected QT dispersion during hemodialysis. *Postgrad Med J.* 2002;78:273–275.

[12] Yildiz A, Akkaya V, Tukek T, et al. Increased QT dispersion in hemodialysis patients improve after renal transplantation: A prospective-controlled study. *Transplantation.* 2001;72:1523–1526.

[13] Yildiz A, Akkaya V, Sahin S, et al. QT dispersion and signal-averaged electrocardiogram in hemodialysis and CAPD patients. *Perit Dial Int.* 2001;21:186–192.

[14] Lorincz I, Matyus J, Zilahi Z, Kun C, Karanyi Z, Kakuk G. QT dispersion in patients with end-stage renal failure and during hemodialysis. *J Am Soc Nephrol.* 1999;10:1297–1302.

[15] Covic A, Diaconita M, Gusbeth-Tatomir P, et al. Hemodialysis increases QT(c) interval but not QT(c) dispersion in ESRD patients without manifest cardiac disease. *Nephrol Dial Transplant.* 2002;17:2170–2177.

[16] Gussak I, Gussak HM. Sudden cardiac death in nephrology: Focus on acquired long QT syndrome. *Nephrol Dial Transplant.* 2007;22:12–14.

[17] Selby NM, McIntyre CW. The acute cardiac effects of dialysis. *Semin Dial.* 2007;20:220–228.

[18] Morris ST, Galiatsou E, Stewart GA, Rodger RS, Jardine AG. QT dispersion before and after hemodialysis. *J Am Soc Nephrol.* 1999;10:160–163.

[19] Beaubien ER, Pylypchuk GB, Akhtar J, Biem HJ. Value of corrected QT interval dispersion in identifying patients initiating dialysis at increased risk of total and cardiovascular mortality. *Am J Kidney Dis.* 2002;39:834–842.

[20] Locsey L, Szlanka B, Menes I, et al. The importance of bioimpedance (BIA) analysis and Cardio Tens (24-h ABPM and ECG) monitoring in the dialysis programme. *Int Urol Nephrol.* 1999;31:547–555.

[21] Grushka E, Garty J, Kristal B, Goldhammer E, Abineder EG, Shasha SM. Cardiac arrhythmia in chronic renal failure: Holter monitoring during hemodialysis and intermittent peritoneal dialysis. *Isr J Med Sci.* 1990;26:378–382.

[22] Wander GS, Sandha GS, Chhabra SC, Khaira NS, Chinna RS. Holter monitoring in chronic renal failure before & during dialysis. *J Assoc Physicians India.* 1994;42:290–293.

[23] Kyriazis J, Kalogeropoulou K, Bilirakis L, et al. Dialysate magnesium level and blood pressure. *Kidney Int.* 2004;66:1221–1231.

[24] Cupisti A, Galetta F, Caprioli R, et al. Potassium removal increases the QTc interval dispersion during hemodialysis. *Nephron.* 1999;82:122–126.

[25] Nappi SE, Virtanen VK, Saha HH, Mustonen JT, Pasternack AI. QTc dispersion increases during hemodialysis with low-calcium dialysate. *Kidney Int.* 2000;57:2117–2122.

[26] Sicouri S, Antzelevitch D, Heilmann C, Antzelevitch C. Effects of sodium channel block with mexiletine to reverse action potential prolongation in in vitro models of the long term QT syndrome. *J Cardiovasc Electrophysiol.* 1997;8:1280–1290.

[27] Shimizu W, Antzelevitch C. Sodium channel block with mexiletine is effective in reducing dispersion of repolarization and preventing torsade des pointes in LQT2 and LQT3 models of the long-QT syndrome. *Circulation.* 1997;96:2038–2047.