Effects of Peritoneal Dialysis on QT Interval in ESRD Patients

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Research article

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Abstract

Background: Patients with chronic kidney disease (CKD) had a high risk of fatal arrhythmias. The extended corrected QT (QTc) interval is a hallmark of ventricular arrhythmias and sudden cardiac death. Studies have shown that QT interval and QTc were prolonged with the declination in renal function. Notably, QTc prolongation is significantly increased in patients undergoing hemodialysis. However, there were no results available in patients with peritoneal dialysis (PD). This study aimed to report the changes in QT interval and QTc in PD patients.

Methods: A total of 66 PD patients were enrolled. The duration of follow-up was 1 year. The demographics, and the etiology of patients were recorded. QTc of ECG and clinical biochemical indexes before dialysis and at 6 months after PD and 1year after PD were determined and analyzed. Dialysis adequacy and peritoneal transport function were assessed in each patient.

Results: (1) A total of 66 PD incident patients, including 50 males and 16 females, with an average age of 43.56±15.15 years (males: 43.74±15.53 years; females: 43.00 ± 15.92 years) were enrolled. In terms of etiology, 37 patients (56.06%) had chronic nephritis, followed by diabetic nephropathy in 11 patients (16.67%), IgA nephropathy with 8 patients (12.12%). The peritoneal transport test showed that the most of the peritoneal transport function was low average transport(25, 37.88%), the least was high transport(2, 3.03%).

(2) During the follow-up period, all patients reached the standard of PD. Compared with baseline before dialysis, anemia, low albumin, blood pressure, blood urea nitrogen, creatinine, uric acid, potassium, calcium, phosphorus and parathyroid hormone were improved after PD at 6 months and 1year. The residual renal function was gradually decreases during the follow-up. There were no significant differences in clinical indexes between 6 months and 1 year after PD.

(3) The mean QTc of all patients were stable during 1-year follow-up period (pre-PD: 413.49±29.95ms; 6 months: 423.05±51.96ms; 1 year: 409.29±32.32ms, P>0.05). According to gender, the QTc in male patients and in female patients had the same results (P>0.05, respectively).

(4) Before PD, diastolic blood pressure (r=-0.261,P=0.039), calcium concentration (r=-0.360,P=0.004) and hemoglobin level (r=-0.432,P=0.000) were found to be the risk factors of QTc prolongation. They were negatively correlated with QTc in end-stage renal disease patients. After patients starting PD, the observed clinical indicators showed no relevance to QTc anymore.

Conclusion: Different from hemodialysis induced QTc prolongation, PD did not increase the patient's QT interval and QTc interval. This phenomenon was reported for the first time, suggesting that myocardial electrical activity might be more stable in PD patients.

Background

Chronic kidney disease (CKD) is an increasing public health issue with an estimated prevalence of 11%-13%[1], and is one of the leading causes of death. CKD patients are associated with increased risk of varied life threatening cardiovascular complications, including ventricular arrhythmias and sudden cardiac death. Cardiovascular disease (CVD) mortality, especially in dialysis patients, is 30 times higher than in general population[2]. Approximately 42% of dialysis patients die due to CVD, with 22.4% of deaths related to cardiac arrest or arrhythmia[3]. QT interval represents the duration of ventricular depolarization and repolarization, and it is closely related to heart rate. The QT interval shortens with accelerating heart rate in normal people, and otherwise extends. So, heart rate is used for correcting the QT interval: corrected QT interval [QTc, QTc = QT/(RR interval in seconds)][1]. A prolonged QTc interval is defined as greater than 440 ms in males and greater than 460 ms in females[4]. Prolonged QTc interval is found in 12.9% of the general

population, and in 20.5% of CKD patients[5]. Also the QTc interval increases by an average of 2.9 ms for each milligram increase in serum creatinine[6].Currently, many studies have proved that QT interval and QTc prolongationhave great significance in predicting malignant ventricular arrhythmia and sudden cardiac death[7,8]. Also other studies[9–11]have proved that with the declination of renal function, both QT interval and QTc are further prolonged, especially in patients with maintenance hemodialysis, showing significantly longer QT interval and QTc after dialysis than before dialysis.

Well, it is still a question as to how QT interval and QTc changes in patients undergoing maintenance peritoneal dialysis (PD)? Therefore, in this study, the changes of QT interval and QTc in peritoneal dialysis patients were analyzed for the first time.

Methods

Study subjects

This is a single-center, retrospective study, and patients with PD from January 1 2018 through May 31 2019 at the first affiliated hospital of Xi'an Jiaotong University were enrolled. The cause of the disease was not limited, with a cut-off age of more than 18 years was set, and included both males and females. The patients were excluded if they have the following conditions: a) acute exacerbation of CKD; b) acute kidney injury; c) contraindications to peritoneal dialysis and incomplete data; d) varied basic cardiac diseases, such as myocardial infarction, myocardial ischemia, cardiomyopathy and cardiac dysfunction; e) varied arrhythmias, such as atrial, junction and ventricular arrhythmias, various conduction blocks, and pacemaker implantation; and f) patients using drugs to prolong QT interval. All eligible patients had no indication to emergency dialysis.

Peritoneal Dialysis Scheme

All patients were treated with manual PD on the day of PD catheter insertion: 1.5% peritoneal fluid, 1000 ml each time, maintained for 1 hour, and the total dialysis dose was 6000 ~ 8000 ml/d. After 10 days, it was changed to 2000 ml each time, and maintained for 4 hours. The total dialysis dose was 6000 ~ 8000 ml/d. After PD for 1 month, peritoneal equilibration test and PD adequacy were performed. According to the D/P value, the peritoneal transport function is divided into four types: low transport, low average transport, high average transport and high transport. Adequacy is calculated using Kt/V and Ccr (renal, peritoneal and total). The PD prescription was adjusted according to the above results. After PD for 6 months and 1year, the dialysis adequacy evaluations were performed again.

Electrocardiograph

The twelve-lead surface electrocardiogram (ECG) was performed at a speed of 25 mm/s and a voltage of 10 mm/mv for all enrolled patients before dialysis, and after PD for 6 months and for 1 year. ECG parameters included heart rate, QT interval and QTc. The QT interval was measured in all leads of ECG, and the longest QT interval was accepted. The start of the QT interval was measured from the beginning of the QRS complex, and the end of the QT interval was measured at the return of the TP baseline or when a U wave was present at the nadir between the T wave and the U wave. The QT interval was measured by an investigator for each patient and was corrected according to heart rate of the patient using Bazett's formula: $QTc = QT/\sqrt{RR(ms)}$, where QTc is the corrected value of the QT interval.

Observation Target

The follow-up time was 1 year. The demographics, clinical biochemical indexes and ECG parameters before dialysis were recorded. After PD for 1 month, the peritoneal transport function was recorded. The clinical biochemical indexes (including blood pressure, hemoglobin, blood urea nitrogen, serum creatinine, uric acid, albumin, potassium, magnesium, sodium, chlorine, calcium, phosphorus, parathyroid hormone, carbon dioxide binding rate, and residual renal function), dialysis adequacy, ECG parameters (including heart rate, QT interval and QTc) were performed at 6-months and 1 year. The residual renal function (RRF) was calculated using the combined 24-h urinary urea and creatinine clearance.

Ethics And Consent To Participate

The study was conducted in accordance with the principles of the Declaration of Helsinki, and the study protocol was approved by the ethics committee of The First Affiliated Hospital of Xi'an Jiaotong University. Because of the retrospective nature of the study, patient consent for inclusion was waived.

Statistical Method

The data were presented as means ± standard deviation for continuous variables. Analysis of variance (ANOVA) was used to test the difference in the mean sample during the follow-up time. Least significant difference (LSD) was further compared whether there was any significant difference between the two groups. Independent-sample t-test was used between the two groups. Multiple linear regression analysis and Pearson correlation coefficient were used to recognize elements related to QTc interval. $P < 0.05$ was considered to be statistically significant. Analyses were performed by employing SPSS (version 22) statistical software package.

Results

Demographics and clinical biochemical indexes before dialysis

A total of 66 PD patients, including 50 males and 16 females,with an average age of 43.56 ± 15.15 years (males: 43.74 ± 15.53 years; females: 43.00 ± 15.92 years) were enrolled. In terms of etiology, 37 patients (56.06%) had chronic nephritis, followed by diabetic nephropathy in 11 patients (16.67%), and IgA nephropathy in8 patients (12.12%), Fig. 1. The peritoneal transport test showed that 25 patients (37.88%) hadlow average transport, 24 patients (36.36%) hadhigh average transport, 15 patients (22.72%) had low transport and 2 patients(3.03%) had high transport,Fig. 2.

Clinical Biochemical Indexes During The Follow-up Period

The clinical biochemical indexes such as systolic blood pressure, diastolic blood pressure, albumin, blood urea nitrogen, creatinine, uric acid, potassium, magnesium, chlorine, phosphorus, calcium, hemoglobin, and carbon dioxide binding rate after PD for 6 months and 1 year were better than those before dialysis, while the blood sodium level was higher and the eGFR(estimated glomerular filtration rate) was lower than that before dialysis, $P < 0.05$ respectively. However, all clinical biochemical indexes at 6 months and 1 year of dialysis remained to be similar, and the differences showed no statistically significant differences ($P > 0.05$), Table 1a-2b.

Table 1

a. Comparison of clinical biochemical indexes during follow-up period

items	systolic blood pressure (mmHg)	diastolic blood pressure (mmHg)	albumin (g/L)	blood urea nitrogen (mmol/L)	creatinine (umol/L)	uric acid (umol/L)	potassium (mmol/L)	magnesium (mmol/L)
pre-PD	148.64 ± 20.13	89.29 ± 15.05	33.82 ± 5.11	31.27 ± 12.38	925.25 ± 343.76	515.55 ± 144.03	4.59 ± 0.83	1.14 ± 0.24
6 months	131.71 ± 20.14	81.93 ± 12.69	38.03 ± 5.16	17.36 ± 4.14	774.30 ± 274.32	386.45 ± 63.70	4.19 ± 0.66	0.99 ± 0.14
1 year	134.77 ± 18.58	84.02 ± 12.06	37.07 ± 4.80	18.98 ± 5.66	888.60 ± 319.12	378.08 ± 75.63	4.11 ± 0.65	0.99 ± 0.13
F value	13.083	4.953	11.972	49.587	3.758	33.843	7.580	13.960
P	0.000	0.008	0.000	0.000	0.025	0.000	0.001	0.000

Table 1

b. Comparison of clinical biochemical indexes during follow-up period

items	Sodium (mmol/L)	Chlorine (mmol/L)	phosphorus (mmol/L)	calcium (mmol/L)	parathyroid hormone (pg/ml)	hemoglobin (g/L)	carbon dioxide binding rate (mmol/L)	eGFR (ml/min)
pre-PD	138.82 ± 4.44	100.38 ± 5.59	2.11 ± 0.60	1.88 ± 0.30	314.65 ± 208.71	83.48 ± 18.12	18.42 ± 3.92	5.76 ± 2.17
6 months	141.88 ± 3.12	98.44 ± 3.50	1.35 ± 0.38	2.13 ± 0.23	327.63 ± 219.86	103.45 ± 20.77	22.95 ± 3.20	3.77 ± 2.70
1 year	141.39 ± 3.25	98.17 ± 3.60	1.49 ± 0.44	2.15 ± 0.17	362.42 ± 240.12	101.02 ± 18.12	23.72 ± 5.05	3.63 ± 5.23
F value	12.207	4.476	42.104	22.597	0.630	20.315	30.097	7.093
P	0.000	0.013	0.000	0.000	0.534	0.000	0.000	0.001

Table 2

a. Comparison of clinical biochemical indexes between Groups during Follow-up Period

	items	systolic blood pressure	diastolic blood pressure	albumin	blood urea nitrogen	creatinine	uric acid	potassium	magnesium
P value	Pre-PD VS 6 months	0.000	0.003	0.000	0.000	0.008	0.000	0.003	0.000
	Pre-PD VS 1 year	0.000	0.036	0.001	0.000	0.513	0.000	0.001	0.000
	6 months VS 1 year	0.417	0.417	0.320	0.319	0.059	0.674	0.583	0.995

Table 2
b. Comparison of clinical biochemical indexes between Groups during Follow-up Period

	items	Sodium	Chlorine	phosphorus	calcium	parathyroid hormone	hemoglobin	carbon dioxide binding rate	eGFR
P value	Pre-PD VS 6 months	0.000	0.016	0.000	0.000	0.747	0.000	0.000	0.002
	Pre-PD VS 1 year	0.000	0.009	0.000	0.000	0.269	0.000	0.000	0.001
	6 months VS 1 year	0.493	0.748	0.140	0.609	0.436	0.507	0.329	0.833

Dialysis Adequacy During The Follow-up Period

In terms of dialysis adequacy, after PD for 6 months and 1 year, the total Kt/v was greater than 1.7(at 6 months: 2.12 ± 0.61; at 1 year: 2.19 ± 0.90; $P = 0.648$), and the total Ccr was more than 50L(at 6 months: 92.37 ± 42.71L; at 1 year: 92.08 ± 71.53L; $P = 0.979$, Table 3). This meant that all the patients have reached the standard of dialysis, and the differences were not statistically significant.

Table 3
Dialysis adequacy during the follow-up period

items	PKt/v	UKt/v	TKt/v	PCcr	UCcr	TCcr
6 months	1.43 ± 0.39	0.67 ± 0.51	2.12 ± 0.61	40.48 ± 8.60	51.90 ± 43.17	92.37 ± 42.71
1 year	1.50 ± 0.41	0.69 ± 1.08	2.19 ± 0.90	43.34 ± 10.30	48.74 ± 77.38	92.08 ± 71.53
t value	-0.823	-0.108	-0.457	-1.586	0.267	0.027
P	0.412	0.914	0.648	0.116	0.790	0.979

Note: PKt/v: peritoneal urea clearance index; UKt/v: renal Urea Clearance Index; TKt/v: total urea removal index; PCcr: peritoneal creatinine clearance rate; UCcr: renal Creatinine Clearance Rate; TCcr: total creatinine clearance rate.

Electrocardiograph Parameters During The Follow-up Period

During the whole follow-up period, the heart rate (pre-PD: 81.9 ± 12.69 bpm; 6 months: 79.55 ± 10.51 bpm; 1year: 80.12 ± 13.48 bpm), QT interval (pre-PD: 378.54 ± 39.60 ms; 6 months: 390.57 ± 54.33 ms; 1 year: 375.88 ± 43.57 ms; $P > 0.05$) and QTc (pre-PD: 413.49 ± 29.95 ms; 6 months: 423.05 ± 51.96 ms; 1 year: 409.29 ± 32.32 ms) of all patients were similar, showing no statistically significant differences ($P > 0.05$) respectively, Table 4 and Table 6. According to gender, the QTc in male patients at 6 months and 1 year of PD was similar (pre-PD: 412.49 ± 30.87 ms; 6 months;424.0 ± 57.86 ms;1 year: 411.9 ± 32.29 ms, $P = 0.363$). Also the female patients obtained similar results [QTc (pre-PD: 416.44 ± 27.79 ms; 6 months;419.56 ± 20.65 ms;1 year: 399.55 ± 31.99 ms, $P = 0.206$], Table 5 and Table 6.

Table 4
Comparison of ECG parameters during the follow-up period

items	Heart rate (bpm)	QT interval(ms)	QTc(ms)
pre-PD	81.90 ± 12.69	378.54 ± 39.60	413.49 ± 29.95
6 months	79.55 ± 10.51	390.57 ± 54.33	423.05 ± 51.96
1 year	80.12 ± 13.48	375.88 ± 43.57	409.29 ± 32.32
F value	0.534	1.365	1.592
P	0.587	0.258	0.207
Note: QTc: corrected QT interval.			

Table 5
Comparison of ECG parameters in different gender during the follow-up period

items	Heart rate (bpm)		QT interval(ms)		QTc(ms)	
	male	female	male	female	male	female
pre-PD	80.91 ± 12.86	84.81 ± 12.11	378.68 ± 40.68	378.13 ± 37.54	412.49 ± 30.87	416.44 ± 27.79
6 months	78.52 ± 10.91	83.33 ± 8.31	393.58 ± 60.15	379.56 ± 21.97	424.00 ± 57.86	419.56 ± 20.65
1 year	77.93 ± 12.27	88.27 ± 15.25	381.32 ± 41.61	355.64 ± 46.74	411.90 ± 32.29	399.55 ± 31.99
F value	0.744	0.437	1.047	1.428	1.023	1.658
P	0.477	0.650	0.354	0.254	0.363	0.206
Note: QTc: corrected QT interval.						

Table 6
Comparison of ECG indexes between groups during follow-up period

	items	Heart rate			QT interval			QTc		
		total	male	female	total	male	female	total	male	female
P value	Pre-PD VS 6 months	0.343	0.386	0.776	0.184	0.166	0.928	0.206	0.212	0.788
	Pre-PD VS 1 year	0.443	0.252	0.481	0.754	0.794	0.137	0.553	0.946	0.128
	6 months VS 1 year	0.826	0.836	0.382	0.120	0.267	0.167	0.081	0.203	0.117
Note: QTc: corrected QT interval.										

Multiple Linear Regression Analysis And Pearson Correlation Coefficient

Before PD, multiple linear regression analysis and Pearson correlation coefficient analysis showed QTc = 511.205−0.870 × diastolic blood pressure − 42.432 × calcium-0.483 × hemogobin. The diastolic blood pressure, calcium concentration and hemoglobin level showed negative correlation with QTc in end-stage renal disease (ESRD) patients, Table 7. But when the patients started PD, the observed clinical indicators did not affect QTc anymore.

Table 7
Influencing factors significantly correlated with QTc prolongation in ESRD (pre-PD)

Characteristics	correlation coefficient (r)	P values
diastolic blood pressure	-0.261	0.039
calcium concentration	-0.360	0.004
hemoglobin	-0.432	0.000

Discussion/conclusion

CKD is an increasing public health problem that can lead to a large number of coronary events[12], and reduced glomerular filtration rate (GFR), which is an independent risk factor of cardiovascular mortality caused by acute myocardial infarction, heart failure, thromboembolic disease and sudden cardiac death (SCD). These events accounted for 26.5% of all-cause mortality and 64% of cardiac mortality in ESRD patients[13,14]. CVD mortality was more higher than in dialysis patients when compared to general population.

QT interval represents the total time course of ventricular depolarization and repolarization. It varies with heart rate. So, heart rate was used to correct the QT interval: corrected QT interval (QTc interval). The extended QTc interval is a hallmark of ventricular arrhythmias, SCD and all-cause mortality[15]. A study has reported that the extended QTc interval was found in 12.9% of the general population when compared with 20.5% of people with CKD[5]. Peng Liu[9], Covic A[10] and Mahmoud Malhis[11] have proved that with the declination of renal function, the QT and QTc interval were further prolonged, especially in maintenance hemodialysis patients, and these indicators were significantly longer after dialysis than before. Well, how will QT and QTc interval changes in patients undergoing maintenance PD? To solve this, the changes of QT and QTc interval were analyzed in PD patients for the first time.

In this study, 66 PD patients, including 50 males and 16 females, were enrolled. Chronic nephritis (37 patients, accounting for 56.06%) was the first cause of chronic renal failure, and the most of the peritoneal transport function showed low average transport, the least showed high transport. Firstly, we observed the therapeutic effect of the patients. During the whole follow-up period, especially after PD for 6 months and for 1 year, the data showed that the dialysis adequacy was up to standard with total Kt/v of greater than 1.7, and total Ccr of greater than 50L. Through regular PD treatment, the blood pressure control, anemia correction, malnutrition, calcium and phosphorus metabolism disorders and acid-base balance disorders of patients showed significant improvement when compared with those before dialysis. At the same time, after PD for 6 months and for 1 year, all clinical indexes were similar, and the differences were not statistically significant.

Secondly, the changes of QT and QTc interval were observed in PD patients during dialysis. Peng Liu[9] showed that the prolongation of QTc interval was worsened by decreased renal function. Among patients with CKD stages 3, 4, and 5 and patients treated with hemodialysis, the proportion of patients with prolonged QTc and severely prolonged QTc was 32.43% and 1.4%, 40.23% and 6.9%, 59.06% and 10.1%, 64.31% and 12.6%, respectively. Covic A[10] and Mahmoud Malhis[11] have proved that QT and QTc interval were significantly increased pre- and post-hemodialysis. But in our study, the data showed that the QT and QTc interval did not extend anymore when patients underwent PD treatment. Due to differences in gender, the definition of QT and QTc interval prolongation remained different, and so the changes of QT and QTc interval before and after PD in male patients and in female patients were compared. The data showed that the QT and QTc interval in male patients were not prolonged before and after PD, and were similar in male patients after PD for 6 months and for 1 year. Similar results were obtained in female patients.

Well, why are the QT and QTc interval significantly longer after hemodialysis than before hemodialysis, while QT and QTc interval showed no significant changes in PD patients? The prolongation of QT interval was due to extended action potential that is caused by increased inward current (ie, the sodium or calcium channels) or a K^+ decreased outward current (ie, potassium channel). The currents (Ikr and Iks) play a key role in myocardial repolarization. A prolonged action potential duration (APD) could lead to early changes after depolarization that are caused by inward depolarizing currents (L-type Ca^{2+} channels and Na^+-Ca^{2+} exchange currents), inducing ventricular arrhythmias like torsade depointes (TdP). In ESRD patients, there were often a serious electrolyte acid-base balance disorder, such as hyperkalemia, hypocalcemia, metabolic acidosis, while potassium, calcium, magnesium and metabolic acidosis are important factors for electrical stability of the myocardium[16,17]. As everyone knows, hemodialysis can quickly correct the electrolyte acid-base balance disorder in ESRD patients. The concentrations of potassium and calcium in dialysate remained low, and so the serum potassium can be quickly removed. However, a large number of studies have shown a negative correlation between QTc interval change and calcium concentrations and potassium reduction during hemodialysis. Sherif *et al*[6] have found that each mmol/L increase of serum K + concentration might result in a 16 ms reduction of the QTc interval. Alabd *et al*[18] have reported a negative correlation between the decrease of serum potassium and the change of QTc interval duration before and after dialysis. The more the serum potassium was decreased, the longer the QTc interval was post dialysis. Genovesi *et al*[19] have found that compared to patients who use dialysate with higher concentrations of potassium and calcium, those patients who use dialysate with lower concentrations of potassium and calcium more likely had QTc intervals of greater than 440 ms. However, the non-prolongation of QT and QTc interval in PD patients might be related to the following aspects: Firstly, compared with hemodialysis, PD has a lower ability to remove toxins per unit time, and so most of PD patients use Continuous Ambulatory Peritoneal Dialysis (CAPD). However, this method avoids drastic changes in the concentrations of various ions present in the serum in a short time, and the concentration of various ions is in a relatively stable state; and secondly, peritoneal dialysate has two different calcium concentrations: physiological calcium and high calcium. Therefore, the appropriate calcium concentration dialysate was chosen for patients according to the patients' serum calcium concentrations. Although peritoneal dialysate included is potassium-free dialysate, the patients had complete pre-dialysis education. They can be supplemented with potassium tablets and eat foods that are rich in potassium during PD to maintain the serum potassium in a stable state and avoid hypokalemia.

As we all know, the blood supply of the heart depends on diastolic perfusion, and the impact on myocardial blood supply will be more direct if the diastolic blood pressure remains too low. This effect is particularly prominent in patients with coronary artery stenosis and left ventricular hypertrophy. Low diastolic blood pressure can cause subendocardial myocardial ischemia that can significantly affect the ventricular repolarization process, resulting in QT and QTc prolongation. Renal anemia is a frequent complication found in patients with CKD. The prevalence of QT prolongation in patients with anemia is common[20,21]. The pathophysiological link between anemia and prolonged QT intervals is probably hypoxia, autonomic dysfunction and decreased myocardial oxygen supply. Impairment of delayed rectifier potassium channels and calcium channels might explain the changes in repolarization[22]. In our study, multiple linear regression analysis and Pearson correlation coefficient showed diastolic blood pressure, calcium concentration and hemoglobin levelas influential factors for QTc prolongation, and were negatively correlated with QTc in ESRD patients. This is similar to the previous research results. However, with the progression of PD, the symptoms and clinical indicators showed significant improvement, and so, the clinical biochemical indexes do not affect the QT interval and QTc anymore.

To sum up, peritoneal dialysis did not increase the patient's QT interval and QTc interval. Myocardial electrical activity might be more stable in patients undergoing PD. This is a single-center retrospective study with small sample and the results might have some limitations. Multi-center study with larger sample size with longer follow-up duration is required to study the effects of PD on QT interval. Therefore, more studies are warranted to explore the effects of PD on QT interval.

Abbreviations

CKD
Chronic Kidney Disease QTc:corrected QT interval
PD
Peritoneal Dialysis CVD:Cardiovascular Disease
Kt/V
urea clearance index Ccr:creatinine clearance rate
ECG
Electrocardiogram RRF:Residual Renal Function
ESRD
End-stage Renal Disease eGFR:estimated Glomerular Filtration Rate
SCD
Sudden Cardiac Death TdP:Torsade depointes
CAPD
Continuous Ambulatory Peritoneal Dialysis

Declarations

BMC Nephrology Declarations Form

Title of Manuscript:

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Competing Interest:

ALL authors have declared that no competing interests exist.

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Ethical Approval

This clinical study was a retrospective study. It only collected the clinical data of patients and did not interfere with the treatment of patients. The study was conducted in accordance with the principles of the Declaration of Helsinki, and the study protocol was approved by the ethics committee of The First Affiliated Hospital of Xi'an Jiaotong University. Because of the retrospective nature of the study, patient consent for inclusion was waived.

Consent for publication: Not Applicable

Trial Registration*(where applicable)*:**None**

The Availability of data and materials:

The data that support the manuscript of this study are available from The First Affiliated Hospital of Xi'an Jiaotong University but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of The First Affiliated Hospital of Xi'an Jiaotong University.

Authors Contributions:

This study was proposed by Prof. JPS and discussed with Dr. WJZ to design this study. WJZ, YuL, JL and YanL jointly screened eligible patients and collected clinical data of all patients. All data were checked by JL and YanL. Statistics were completed by WJZ and YuL. The manuscript was written by WJZ and YuL, and was reviewed by Prof. JPS. All authors had read and approved the manuscript.

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Figures

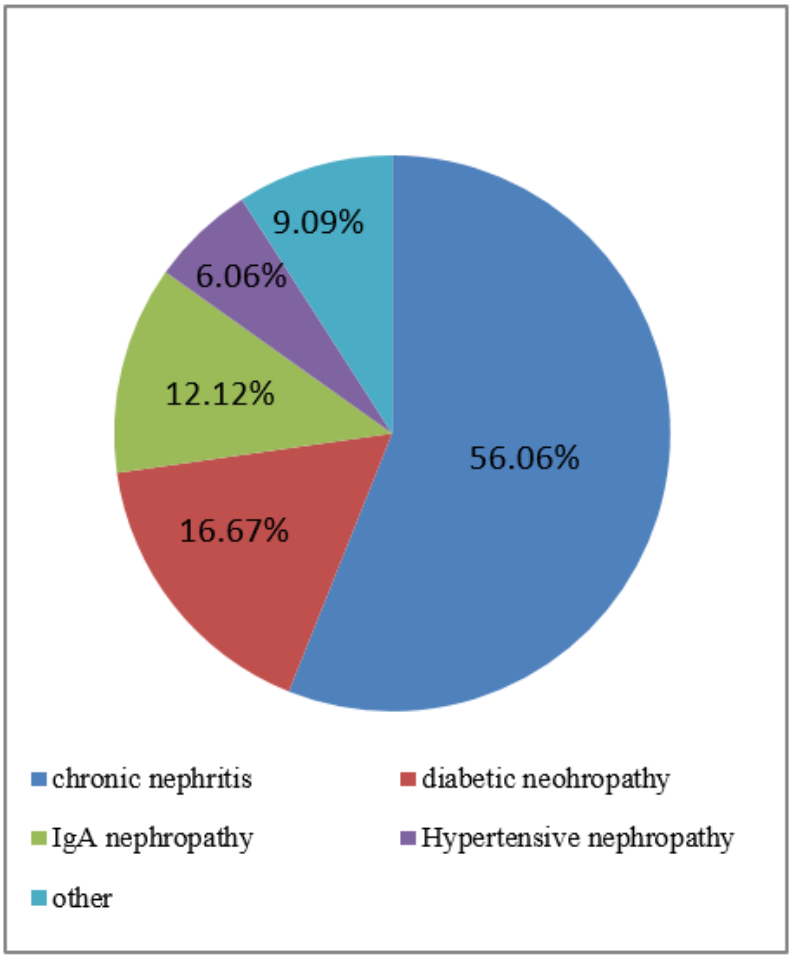

Figure 1

etiology for all patients

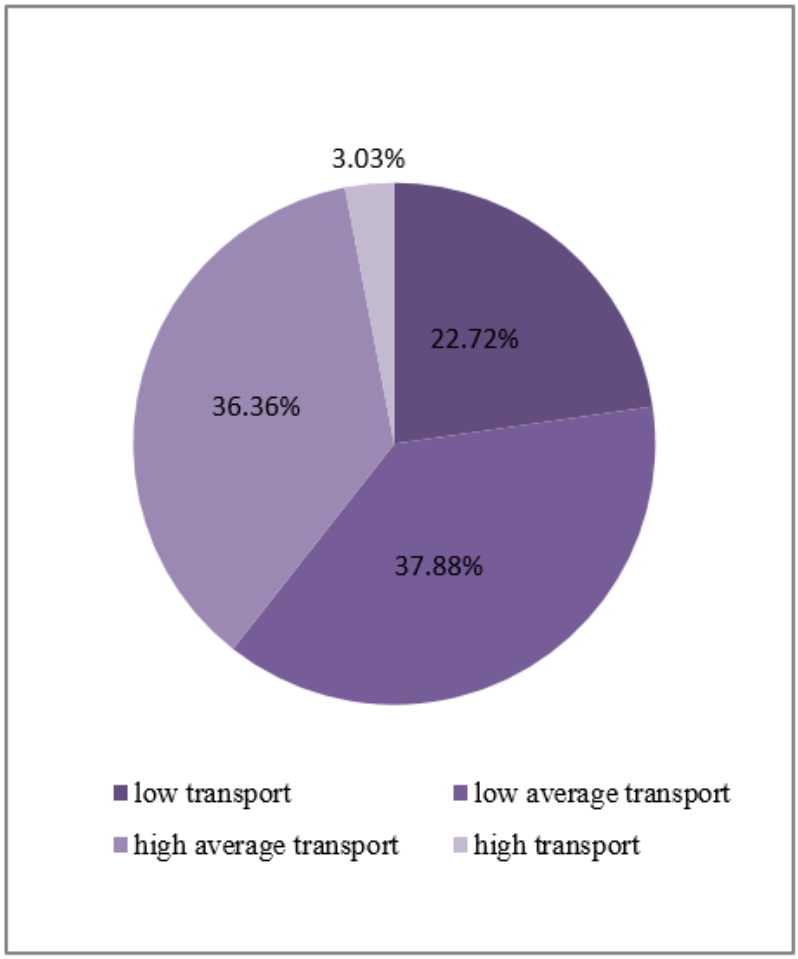

Figure 2

peritoneal transport function