European Review for Medical and Pharmacological Sciences 2023; 27: 3837-3845

Risk factors and etiological characteristics of urinary tract infection in hospitalized continuous ambulatory peritoneal dialysis patients

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Abstract. – OBJECTIVE: This study aimed to explore the risk factors and etiological characteristics of urinary tract infection (UTI) in continuous ambulatory peritoneal dialysis (CAPD) patients.

PATIENTS AND METHODS: A total of 90 CAPD patients with UTI comprised the infection group, while 32 CAPD patients without UTI constituted the control group. The risk factors and etiological characteristics of UTI were analyzed.

RESULTS: Of the 90 bacterial strains isolated, 30 were Gram-positive (33.3%) and 60 were Gram-negative (66.7%). Urinary stones or urinary tract structural changes were more prevalent in the infection group (71.1%) than in the control group (46.9%) ($\chi^2 = 6.076$, $p = 0.018$). The proportion of patients with residual diuresis less than 200 ml was higher in the infection group (50%) than in the control group (15.6%) ($\chi^2 = 11.533$, $p = 0.001$). The distribution of primary disease differed between the two groups. Patients in the infection group had higher CAPD vintage, levels of triglycerides, fasting blood glucose, blood creatinine, blood phosphorus, and calcium-phosphorus product than those in the control group. Multivariate binary logistic regression analysis indicated that residual diuresis less than 200 ml (OR = 3.519, $p = 0.039$) and urinary stones or structural changes (OR = 4.727, $p = 0.006$) were independent risk factors for UTI.

CONCLUSIONS: Urine cultures of CAPD patients with UTI contained a complex distribution of pathogenic bacteria. Urinary stones or structural changes and residual diuresis less than 200 ml were independent risk factors for UTI.

Key Words:
CAPD, UTI, Bacterial infection, Urine culture.

Abbreviations

UTI: urinary tract infection; CAPD: continuous ambulatory peritoneal dialysis; CKD: chronic kidney disease; CAKUT: congenital anomalies of the kidneys and urinary tracts; MRSA: Methicillin-Resistant Staphylococcus Aureus; ESBL: Extended Spectrum β-Lactamase; ESRD: end-stage renal disease; PTH: parathyroid hormone.

Introduction

Chronic kidney disease has been recognized as a leading public health problem worldwide[1,2]. Without rational treatment, patients suffering from this condition mostly end up on dialysis. Continuous ambulatory peritoneal dialysis (CAPD) is a common renal replacement therapy for patients with end-stage renal disease (ESRD)[3]. The complications associated with CAPD include peritonitis, infection at the exit, and infection of the tunnel[4]. Although urinary tract infections (UTIs) are common in CAPD patients according to our clinical experience, they have hardly been investigated in this context. Information is limited about the clinical manifestations of UTIs in this population as well as the distribution and drug resistance of the associated microflora. Identifying the risk factors for UTIs in CAPD patients and determining whether the infection affects their prognosis is necessary.

In this study, we investigated the microflora distribution and factors influencing UTIs in CAPD patients. The purpose of this study was to provide a basis for antibiotic selection when CAPD patients contract UTIs in the clinical setting. The risk factors for UTIs were analyzed. Based on our findings, we recommend tighter control over susceptibility factors to prevent CAPD patients from contracting UTIs.

Patients and Methods

Study Population

Study subjects were selected from CAPD patients with residual urine volume that were admitted to the Department of Nephropathy, the First Affiliated Hospital of Anhui Medical University between June, 2015, and June, 2021. The patients' residual urine volume had to satisfy the requirements for complete urine analysis and urine culture (Figure 1). Patients were admini-

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stered peritoneal dialysis fluid with 1.5% or 2.5% glucose (Huaren Pharmaceutical, China; 2 L/bag) thrice or four times daily. Patients with suspected UTI symptoms or abnormal urinalysis but negative urine cultures were excluded. Some dialysis patients were misdiagnosed with UTI due to low urine output and abnormal concentration of urinary leukocytes or cellular debris[5].

Inclusion criteria for the infection group included a positive urine bacterial culture and no other systemic infections. Inclusion criteria for the control group included a negative urine bacterial culture, no typical symptoms of UTI, and no other systemic infections.

Subjects were excluded from the study in the following scenarios:

1. The purpose of this hospitalization was to perform peritoneal dialysis catheterization.
2. They showed typical symptoms of UTI, but their urine culture was negative.
3. They failed to follow the aseptic principle while collecting urine, resulting in false positive urine cultures. The culture result indicated a mixed infection due to three or more bacteria, which is judged as a false positive according to our laboratory standards. The inflammatory indicators and urine analysis of these patients were completely normal.
4. Their urine cultures tested positive for fungi.
5. They had been given antibiotics outside the hospital.
6. They had other systemic infections.
7. Their clinical data were incomplete.

Data Collection

Sociodemographic, clinical, and laboratory data of patients were obtained from an electronic medical records database. Sociodemographic data included name, age, sex, weight, height, and body mass index. Clinical data included basic diseases (diabetes, rheumatic diseases, chronic hepatitis B, etc.), mode of CAPD (type of dialysis solution and frequency of dialysis), the CAPD vintage, exit site score, peritoneal equilibration test, adequacy of CAPD, ultrafiltration volume, and residual diuresis. Laboratory data comprised urine culture and drug sensitivity results, liver function, kidney function, levels of hemoglobin, blood lipids, blood electrolytes, blood glucose, parathyroid hormone, calcium-phosphorus product, C-reactive protein, procalcitonin, and iron metabolism indicators, B-ultrasound or other imaging data of the urinary system to confirm the presence of congenital anomalies of the kidneys and urinary tracts, and reflux nephropathy or obstructive uropathy.

Definition of Variables and Outcomes

Patients were judged to have UTIs if they showed the expected symptoms and the bacterial count in their urine was $\geq 10^5$/ml. Asymptomatic bacteriuria, characterized by no symptoms of UTI but two positive urine cultures of the same species, was classified as a UTI in this study. The standard diagnosis of bacteriuria includes a bacterial colony count $\geq 10^5$/ml in urine cultures. To avoid subjecti-

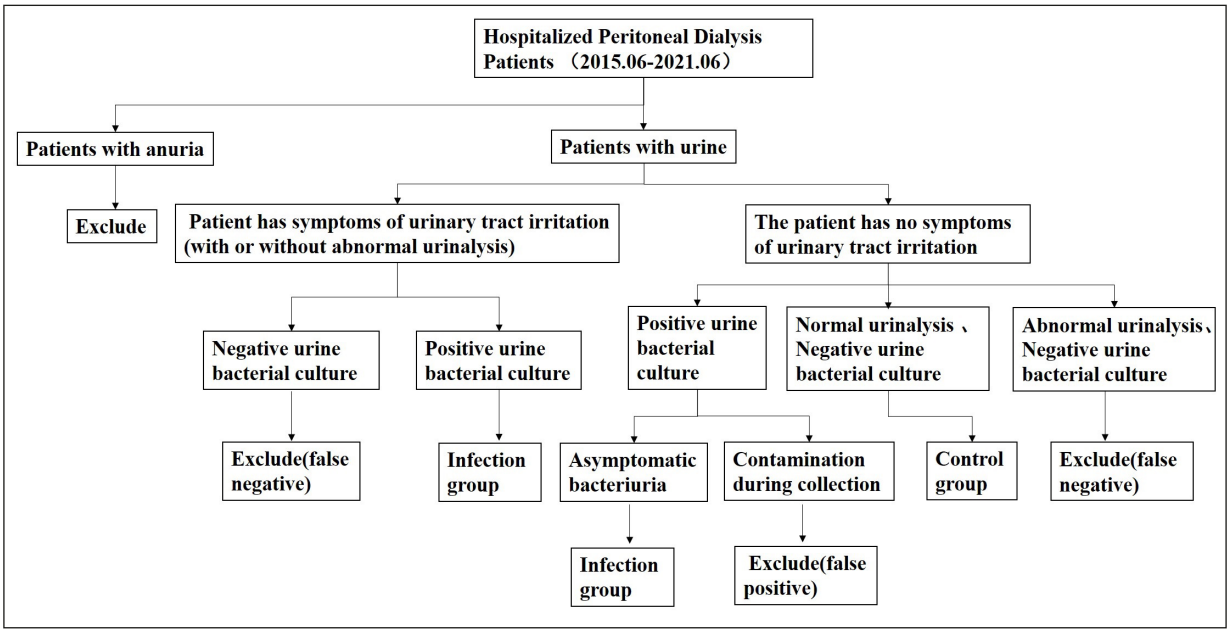

Figure 1. Participants inclusion and exclusion process.

ve diagnosis bias, patients with typical symptoms of UTI but negative urine cultures were not included in this study. In addition, some patients in this study did not have enough urine, so midstream urine was not strictly required. These patients were instructed at the bedside by nurses before their urine was sampled. Urine was collected when they felt the urge to urinate after adequately cleaning the vulva. Urine samples from all subjects were collected when they were admitted to the hospital.

In this study, the urinary system B-ultrasound suggested the presence of stones or structural changes, indicating obvious kidney atrophy, prostatic hyperplasia, high blood flow resistance, or polycystic changes.

Statistical Analysis

Data were analyzed using SPSS version 23 (IBM Corp., Armonk, NY, USA). Measurement data: normally distributed data were expressed as the mean ± standard deviation ($\bar{x} \pm s$). If the variance was homogeneous, groups were compared using the *t*-test. If the variance was uneven, groups were compared using the Satterthwaite approximation method. Non-normal data were expressed as quartiles, and the non-parametric rank sum test was used to compare between groups. Counting data were expressed as percentages (%). If the sample size $n < 40$ or the theoretical frequency $T < 1$, the Fisher's exact probability method was used to compare between groups. If the sample size $n \geq 40$ or the theoretical frequency $T \geq 5$, the χ^2 test was used to compare between groups. If the theoretical frequency $1 \leq T < 5$, the corrected χ^2 test was used. Factors with $p < 0.05$ in the univariate analysis were included in the binary logistic regression analysis. $p < 0.05$ was considered statistically significant.

Results

Patients' Urinalysis and Symptoms on Admission

In the infected group, 5/90 patients were positive for nitrite, 50/90 for leukocyte esterase, and 37/90 for glucosuria (Table I). The number of pus cells significantly differed between the infection and the control groups ($p < 0.001$). Upon admission, five patients from the infection group had fever and 73 showed symptoms of urinary tract irritation.

Patients' Baseline Characteristics

The infection group comprised 14 males and 76 females, with an average age of 52 ± 13 years. The control group comprised 10 males and 22 females, with an average age of 52 ± 12 years. The gender and age characteristics of the two groups were matched. There was also no difference in socio-economic status between the two groups. In terms of the primary disease, the infection group included 13 cases of chronic glomerulonephritis, 5 of diabetic nephropathy, 35 of hypertensive nephropathy, 12 of polycystic kidney disease, and 25 of other or unknown causes. The control group was constituted of 10 cases of chronic glomerulonephritis, 6 of hypertensive nephropathy, 7 of polycystic kidney disease, and 9 of other or unknown causes.

Peritoneal dialysis vintage ($p = 0.008$), triglycerides ($p < 0.001$), fasting blood glucose ($p = 0.039$), creatinine ($p = 0.040$), blood phosphorus ($p = 0.017$), and calcium-phosphorus product ($p = 0.001$) were higher in the infection group than in the control group (Table II). More patients carried urinary stones or showed urinary tract structural changes in the infection group than in the control group (71.1% *vs.* 46.9%, $p = 0.018$). More patients in the infection group (50%) had residual diuresis less than 200 ml than in the control group (15.6%, $p = 0.001$). The primary disease in the infection group was mainly hypertensive nephropathy, while that in the control group was chronic glomerulonephritis. The distribution of polycystic kidney disease and diabetic nephropathy was similar between the two groups. Kt/V, exit site score, blood albumin, hemoglobin, transferrin, total cholesterol, eGFR, urea nitrogen, uric acid, blood calcium, serum sodium, serum potassium, parathyroid hormone, and the dialysate glucose content did not significantly differ between the two groups.

Multivariate Logistic Regression Analysis of UTI in Patients with CAPD

Influential factors with $p < 0.05$ in the single factor analysis were substituted into the binary logistic regression equation (Table III). We found that residual diuresis less than 200 ml (OR = 3.519, $p < 0.05$) and urinary stones or structural changes (OR = 4.727, $p < 0.05$) were independent risk factors for UTI.

The Distribution and Composition Ratio of Pathogenic Bacteria in CAPD Patients with UTI

Among the 90 CAPD patients with positive urine cultures, 30 carried Gram-positive bacteria (33.3%) and 60 carried Gram-negative bacteria (66.7%, Table IV). *Escherichia coli* and *Enterococcus faecalis* were the two most common bacteria.

Table I. Patients' urinalysis and symptoms on admission.

		Control group (n = 32)	Infection group (n = 90)	*p*-value
Nitrite	*+Ve*	0	5	–
	-Ve	32	85	
Leukocyte esterase	*+Ve*	0	50	–
	-Ve	32	40	
Glucosuria	*+Ve*	12	37	0.128
	-Ve	20	53	
Pus cells number pcs/ul		3 (1, 6)	88 (16, 322)	< 0.001
Clinical findings				
Fever	*YES*	0	5	–
	NO	32	85	
Urinary tract irritation	*YES*	0	73	–
	NO	32	17	

"-" = not available, *+Ve*: positive, *-Ve*: negative.

Susceptibility Results of Major Gram-Positive Bacteria

The resistance rates of *E. faecalis* to levofloxacin, ciprofloxacin, and gentamicin were 50% (Table V). *E. faecium* isolated from three cases was completely resistant to levofloxacin, ciprofloxacin, erythromycin, and penicillin. The resistance rates of *E. faecium* to ampicillin and gentamicin were more than 30%. All Gram-positive bacteria (including four cases of methicillin-resistant *Staphylococcus aureus*) were sensitive to vancomycin and linezolid.

Susceptibility Results of Major Gram-Negative Bacteria

The resistance rate of *E. coli* to ampicillin was 76.67%, while that to ampicillin-sulbactam, ceftazidime, ceftriaxone, gentamicin, ciprofloxacin, trimethoprim-sulfamethoxazole, piperacillin, or levofloxacin was more than 30% (Table VI). *Klebsiella pneumoniae* was completely resistant to ampicillin, while its resistance rates to ampicillin-sulbactam, ceftriaxone, trimethoprim-sulfamethoxazole, and piperacillin were greater than 30%. The main Gram-negative bacteria were sensitive to piperacillin tazobactam, imipenem, and amikacin. Among *E. coli* strains, those that produced extended-spectrum β-lactamases displayed higher resistance rates to penicillin, cephalosporins, aminoglycosides, and quinolones than those that did not.

Discussion

In this study, Gram-negative bacteria were the most commonly detected microbes from UTI cultures of CAPD patients. Their distribution mainly included *E. coli, E. faecalis, K. pneumoniae*, and *E. aerogenes*, which is similar to previously reported microflora distributions in related UTIs[6,7]. The resistance spectrum of *E. coli* was widespread, encompassing cephalosporins and penicillin. The common Gram-negative bacteria were sensitive to piperacillin-tazobactam, imipenem, and amikacin, while the Gram-positive bacteria (including four cases of methicillin-resistant *S. aureus*) were widely resistant to quinolones and penicillin, but sensitive to vancomycin and linezolid. The drug resistance rate of UTIs has increased, and their resistance spectrum has broadened due to the widespread use of antibiotics[8,9]. More stringent control is required over the indications of antibiotic use in clinical work. The choice of antibiotics and the course of treatment need to be more cautiously decided for dialysis patients[10].

A higher proportion of patients in the infection group than in the control group had urinary stones or showed urinary tract structural changes (71.1% *vs.* 46.9%). In this study, "urinary tract structural changes" indicated obvious kidney atrophy, prostatic hyperplasia, high blood-flow resistance, or polycystic changes. Patients with ESRD were more likely to develop infections in the urinary system, and they exhibited symptoms of lower urinary tract irritation after dialysis[11]. Patients' bladder capacity, bladder compliance, and urodynamics gradually decrease with increasing dialysis time[12]. About 48.4% of ESRD patients had abnormal cystoscopy results, including mucosal fissures, bladder trabeculae, and polyp formation, indicating the presence of chronic inflammation and urothelial dysfunction in the bladders of these patients[13].

As the dialysis vintage increased, patients' urine volume decreased, the flushing effect on the urethra weakened, and urine composition

Table II. Single factor analysis of UTI in CAPD patients [M (P_{25}, P_{75})].

Group	Control group (n = 32)	Infection group (n = 90)	Statistics (t, χ^2, Z)	p-value
Age (years old, $x \pm s$)	52 ± 12	52 ± 13	0.012	> 0.990
Gender (n)				
Male	10	14	3.68	0.055
Female	22	76		
Socio-cultural status				
Junior high school and below	27	81	0.286	0.593
High school and above	5	9		
Residual diuresis (ml/24 h)	750 (425, 1,100)	225 (100, 600)	-4.196	0.001
Whether the residual diuresis was less than 200 ml (n)				
Yes	5	45	11.533	0.001
No	27	45		
Whether the primary disease was polycystic kidney (n)				
Yes	7	12	0.741	0.389
No	25	78		
Whether the primary disease was chronic glomerulonephritis (n)				
Yes	10	13	4.358	0.037
No	22	77		
Whether the primary disease is diabetic nephropathy (n)				
Yes	0	5	0.71	0.400
No	32	85		
Whether the primary disease is hypertensive nephropathy (n)				
Yes	6	35	4.291	0.038
No	26	55		
Whether there were stones or structural changes in both kidneys (n)				
Yes	15	64	6.076	0.018
No	17	26		
The dialysate glucose content				
1.50%	28	68	2.008	0.156
2.50%	4	22		
Use of high glucose dialysate ≥ 2 bags/d				
Yes	0	11	2.938	0.087
No	32	79		
Peritoneal vintage (months)	6 (1, 12)	12 (2, 36)	-2.657	0.008
Kt/V	1.8 (1.6, 2.3)	1.9 (1.4, 2.2)	-0.472	0.637
Exit site score (score)	0 (0, 1)	0 (0, 1)	-0.036	0.971
Blood albumin (g/L, $x \pm s$)	34.1 ± 4.0	34.1 ± 5.8	0.022	0.983
Hemoglobin (g/L, $x \pm s$)	102 ± 19	99 ± 25	0.606	0.546
Transferrin (mmol/L, $x \pm s$)	1.8 ± 0.4	1.7 ± 0.4	1.105	0.271
Total cholesterol (mmol/L)	4.6 (3.7, 5.7)	4.8 (4.0, 5.2)	-0.632	0.528
Triglyceride (mmol/L)	1.1 (0.8, 1.5)	1.5 (1.2, 2.7)	-3.568	<0.001
Fasting blood glucose (mmol/L)	4.4 (4.2, 5.1)	4.8 (4.3, 5.8)	-2.066	0.039
eGFR (ml/min/1.73 m^2)	5.5 (4.3, 8.0)	5.0 (4.0, 7.0)	-1.865	0.062
Creatinine (μmol/L)	730.1 (584.7, 907.3)	861.2 (652.8, 1,087.0)	-2.049	0.040
Urea nitrogen (mmol/L)	17.8 (13.2, 22.4)	18.8 (15.5, 21.3)	-0.643	0.520
Uric acid (μmol/L)	414 (386, 489)	418 (382, 483)	-0.169	0.866
Blood calcium (mmol/L)	2.2 (2.1, 2.3)	2.2 (2.1, 2.4)	-1.651	0.099
Blood phosphorus (mmol/L)	1.5 (1.2, 1.8)	1.8 (1.4, 2.2)	-2.378	0.017
Serum sodium (mmol/L)	139.9 (138.3, 141.0)	139.1 (136.9, 141.1)	-0.824	0.410
Serum potassium (mmol/L)	3.8 (3.5, 4.2)	3.7 (3.3, 4.1)	-0.832	0.405
Calcium-Phosphorus Product	40.0 (33.3, 43.2)	49.1 (36.5, 56.5)	-3.265	0.001
Parathyroid hormone (ng/L)	289 (144, 468)	176 (80, 417)	-1.708	0.088

UTI = urinary tract infection, CAPD = continuous ambulatory peritoneal dialysis. Kt/V = K dialyzer clearance of urea, t = dialysis time, V = volume of distribution of urea.

Table III. Multivariate binary logistic regression analysis of UTI in CAPD patients.

	B	*SE*	OR	95% CI	*p*-value
Peritoneal dialysis age (for each additional month)	0.005	0.016	1.005	0.974-1.037	0.762
Triglyceride	0.484	0.281	1.623	0.936-2.815	0.085
Fasting blood glucose	0.315	0.231	1.371	0.872-2.156	0.172
Creatinine	0.000	0.001	1.000	0.998-1.002	0.815
Blood phosphorus	1.788	1.651	0.163	0.007-4.253	0.279
Calcium and phosphorus product (for each additional unit)	0.098	.061	1.103	0.978-1.244	0.109
Residual diuresis was less than 200 ml (take residual diuresis ≥ 200 ml as reference)	1.258	0.610	3.519	1.065-11.626	0.039
Whether the primary disease is hypertensive nephropathy	0.882	0.653	2.416	0.627-8.692	0.177
Whether the primary disease was chronic glomerulonephritis	0.442	0.645	0.643	0.182-2.277	0.494
Whether there were stones or structural changes in both kidneys	1.553	0.564	4.727	1.564-14.289	0.006

UTI = urinary tract infection, CAPD = continuous ambulatory peritoneal dialysis, *B* = regression coefficient, SE = standard error, OR = odds ratios, 95% CI = 95% confidence interval.

Table IV. Distribution and composition ratio of pathogenic bacteria in CAPD patients with UTI.

Pathogen	Number of plants (n = 90)	Composition ratio (%)
Gram-negative bacteria	60	66.67
Escherichia Coli	30	33.33
Klebsiella pneumoniae	6	6.66
Enterobacter aerogenes	5	5.55
Enterobacter cloacae	4	4.44
Proteus	3	3.33
Other rare bacteria	12	13.33
Gram-positive bacteria	30	33.33
Enterococcus faecalis	12	13.33
Enterococcus faecium	3	3.33
Streptococcus	7	7.77
Staphylococcus	7	7.77
Enterococcus raffinose	1	1.11

UTI = urinary tract infection, CAPD = continuous ambulatory peritoneal dialysis.

Table V. Drug susceptibility results of main gram-positive bacteria.

Types of antibiotics	*Enterococcus faecalis* (n = 12)			*Enterococcus faecium* (n = 3)		
	S	R	Resistance rate (%)	S	R	Resistance rate (%)
Levofloxacin	6	6	50.00	0	3	100.00
Streptomycin	7	5	41.67	2	1	33.33
Ampicillin	11	1	8.33	1	2	66.67
Ciprofloxacin	6	6	50.00	0	3	100.00
Erythromycin	9	1	8.33	0	3	100.00
Gentamicin	6	6	50.00	1	2	66.67
Moxifloxacin	-	-	-	-	-	-
Penicillin	11	1	8.33	0	3	100.00
Tetracycline	1	11	91.67	2	1	33.33
Vancomycin	12	0	0.00	3	0	0.00
Linezolid	10	-	-	3	0	0.00
Tigecycline	11	-	-	1	-	-

"-" = not tested, S = sensitive, R = resistance.

changed. Urine pH[14], osmotic pressure, and urea changes played a role in the occurrence of UTI. The antimicrobial activity of granulocytes, macrophages, and other immune responses was inhibited by various uremic toxins[15]. In addition, CAPD patients were more likely to develop UTI

Table VI. Drug susceptibility results of main gram-negative bacteria.

Types of antibiotics	*Escherichia coli* (n = 30)			*Klebsiella pneumoniae* (n = 6)		
	S	R	Resistance rate (%)	S	R	Resistance rate (%)
Ampicillin	7	23	76.67	0	6	100.00
Ampicillin-Sulbactam	9	13	43.33	3	2	33.33
Piperacillin-Tazobactam	29	-	-	6	0	0.00
Cefotetan	29	1	3.33	5	0	0.00
Ceftazidime	21	9	30.00	6	0	0.00
Ceftriaxone	14	16	53.33	4	2	33.33
Imipenem	30	0	0.00	-	0	0.00
Amikacin	30	0	0.00	-	0	0.00
Gentamicin	20	9	30.00	-	0	0.00
Tobramycin	21	3	10.00	-	0	0.00
Ciprofloxacin	17	13	43.33	5	1	16.67
Trimethoprim-Sulfamethoxazole	13	17	56.67	3	3	50.00
Piperacillin	6	9	30.00	1	2	33.33
Cefoperazone-Sulbactam	20	2	6.67	-	0	0.00
Tigecycline	25	-	-	-	0	0.00
Levofloxacin	16	9	30.00	5	0	0.00

"-" = not available, S = sensitive, R = resistance.

under the influence of multiple risk factors, such as high levels of blood creatinine, urea, uric acid, and glucose exposure[16]. UTI in CAPD patients can develop into bacteremia, septic shock, etc., which endangers the normal progress of CAPD[17,18]. Reducing the occurrence of UTI could delay the decrease in urine volume and protect residual kidney function[19-21], which helps CAPD patients to remove toxins and achieve a metabolic balance of trace elements[22,23]. Residual renal function was found to reduce inflammation in CAPD patients[24,25].

Disorders of calcium-phosphorus metabolism were found to occur more likely in patients with chronic kidney disease[26]. Calcium-phosphorus products accumulated to a significantly higher level in the infection group than in the control group. Metabolic disorders involving minerals can cause bone pain and malformations, calcification of soft tissues, blood vessels, and heart valves, high incidence of cardiovascular events, and secondary hyperparathyroidism, all of which potentially reduce the quality of life[27]. The differences in calcium-phosphorus metabolism between the two groups suggest that it may be involved in the development of UTI[28,29]. Renal vascular calcification results in insufficient renal blood perfusion, which impairs urine production and residual renal function[30].

In this study, the infection group had higher levels of triglycerides and fasting blood glucose. The increase in glucose concentration in CAPD patients was due to the long-term use of high-glucose and hypertonic dialysate, which stimulated the pancreas to secrete insulin. Disorders of lipid metabolism and insulin resistance occurred due to high-glucose stimulation. Patients showed impaired leukocyte functions. High levels of fasting blood glucose have been shown[31] to attenuate the chemotaxis, adhesion, phagocytosis, and bactericidal activities of multinucleated cells and monocytes. Such patients were prone to infection complications[32]. In addition, glucose exposure can probably predict progression to anuria[33].

Although the two groups in this study were age- and gender-matched, female CAPD patients were found to be at a higher risk of UTI than males because their urethra was short, wide, and straight[34]. The difference in primary disease between the two groups might also impact the incidence of UTI in CAPD patients. In this study, the control group was mainly suffering from chronic glomerulonephritis, while the primary disease in the infection group was hypertensive nephropathy, which may be caused by atherosclerosis as a result of hypertension and decreased renal perfusion[35]. Hypertension can also be caused by some congenital abnormalities, such as vesicoureteral reflux and renal scarring, but urinary ultrasound confirmed the absence of any such abnormalities. However, B-ultrasound has limitations for vesicoureteral reflux detection, and voiding cystourethrography is the gold standard.

This study emphasizes the importance of reducing the incidence of UTI in CAPD patients. Perfecting urine culture was suggested for female patients regardless of the presence of UTI

symptoms[36], for patients with longer CAPD vintage, less residual diuresis, and urinary stones or urinary tract structural changes. The type of antibiotics should be selected based on the susceptibility results of the patients' urine cultures. Clinicians need to strengthen all aspects of CAPD patient management, and actively intervene to control various risk factors by maintaining blood pressure within a reasonable range, adjusting blood glucose and blood lipid values, maintaining the balance of calcium-phosphorus metabolism, improving anemia, controlling weight, and using diuretics appropriately according to the patients' condition. Patients need to pay attention to the hygiene and care of the perineum. Patients' CAPD mode could be extended and their quality of life improved by preventing and controlling various risk factors.

The retrospective analysis used in this study might engender selection bias. Prospective studies in the future should assess the differences in urine volume, residual renal function, survival rate, and failure rate of CAPD between the two groups of patients. In addition, the patients' vesicoureteral reflux should be estimated to confirm its impact on the incidence of UTI.

Conclusions

E. coli was the main etiological agent for UTI in CAPD patients, followed by *E. faecalis* and *K. pneumoniae*. Anti-infective programs need to be formulated strictly based on drug susceptibility results because these bacteria were found to be highly resistant. Urinary stones or structural changes in the urinary tract and residual diuresis less than 200 ml were independent risk factors for UTI in CAPD patients.

Acknowledgments
We thank the medical record room of the First Affiliated Hospital of Anhui Medical University for the information and the Laboratory Department of the First Affiliated Hospital of Anhui Medical University for the data provided.

Conflict of Interest
The authors declare that they have no competing interests.

Availability of Data and Materials
The datasets generated and analyzed during the current study are not publicly available due to privacy but are available from the corresponding author on reasonable request.

Informed Consent
The institutional review board of the center approved this study and waived the requirement for informed consent because only anonymized data were examined.

Ethics Approval
The study protocol and data application were approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University (PJ2019-17-10).

Funding
This study was supported by grants from National Natural Scientific Foundation of China (81900697). It played roles in financing, study design, administration, data analysis and preparation of the manuscript.

Authors' Contributions
X.-M. Luo and Y.-G. Wu conceived and designed the study. Y.-Y. Li and X.-M. Qi prepared Figure 1 and Tables I-VI. X.-M. Luo analyzed and interpreted the data, and X.-M. Luo wrote the main manuscript text. All authors reviewed the manuscript.

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