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Effect of a Management Algorithm for Wet Contamination of Peritoneal Dialysis System on the Prevention of Peritonitis: A Prospective Observational Study

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Keywords

Peritoneal dialysis · Wet contamination · Peritonitis · Management algorithm · Prevention

Abstract

Introduction: Wet contamination was a common problem of peritoneal dialysis (PD) system. We developed a management algorithm for wet contamination of PD system (wet contamination) on the basis of the related research literature and clinical practice experience. The purpose of this study was to observe clinical effect of the management algorithm on the prevention of peritonitis. ***Methods:*** Patients treated wet contamination in a single PD center between October 2017 and September 2022 were included. A management algorithm was established to treat wet contamination. It comprised identification of the contamination type, addressing contaminated or aging catheters, prophylactic antibiotics, and retraining. Demographic data and clinical data about wet contamination were collected and compared. ***Results:*** One hundred and forty-one cases of wet contamination were included in this study. The mean age was 51.7 ± 14.1 years, and 49.6% were female. The proportion of diabetic nephropathy was 9.9%. The median PD duration was 27.0 (1.7–79.7) months. Eighteen episodes (12.8%) of wet contamination-associated peritonitis developed after wet contamination. The main pathogenic bacteria of peritonitis were Gram-positive bacteria (33.3%) and Gram-negative bacteria (27.8%). The incidence of wet contamination-associated peritonitis in the compliance with the management algorithm group was significantly lower than that in the non-compliance with the management algorithm group (0.9 vs. 48.6%; $p < 0.001$). Non-compliance with management algorithm (OR = 185.861, $p < 0.001$) together with advance age (OR = 1.116, $p < 0.001$) and longer distance from home to hospital (OR = 1.007, $p < 0.001$) were independent risk factors for wet contamination-associated peritonitis. ***Conclusion:*** The management algorithm for wet contamination of PD system could reduce the risk of peritonitis.

Introduction

Peritoneal dialysis (PD)-associated peritonitis is a serious complication in PD patients, and prevention and treatment are very important in reducing substantial

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morbidity, technique failure, and mortality [1]. In this study, wet contamination of PD system ("wet contamination") was defined as contamination with an open PD system; i.e., the dialysate was infused after the contamination, or the catheter transfer set was open for an extended period [2, 3]. Wet contamination could allow entry of bacteria from the external environment into the peritoneal cavity through PD catheter and cause peritonitis [4]. It was a modifiable risk factor for peritonitis in the 2016 peritonitis guideline of the International Society of Peritoneal Dialysis [2]. However, few studies have proposed a treatment for wet contamination in PD patients and observed the effect of the therapeutic regimen [3, 4]. Therefore, we established a management algorithm for wet contamination that was based on clinical practice experience in our PD center, relevant guidelines [2, 5], and the research literature [3]. The hypothesis of this study was that a management algorithm for wet contamination could help reduce the risk of PD-associated peritonitis.

Methods

Participants

This prospective observational study recruited PD patients in a single PD center in southern China between October 2017 and September 2022. The inclusion criteria were that PD patient developed wet contamination of the PD system and accepted treatment at our PD center. Those PD patients who coexisted gastrointestinal or other organ infection, or experienced serious complications that significantly interfere with the evaluation of wet treatment efficacy, or accepted invasive procedures or operations simultaneously were excluded. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the First Affiliated Hospital of Sun Yat-sen University (Ethical Review [2016] 215). All PD patients had accepted training at our hospital after PD catheter insertion. The content of training included a standard dialysate exchange procedure, the protection of PD catheter, the method of contamination identification, and contacting medical staff promptly. After training, each PD patient accepted assessment. He or she should represent the training content correctly.

Management Algorithm for Wet Contamination of the PD System

The management algorithm for wet contamination of the PD system comprised identification of the contamination type, addressing contaminated or aging catheters, prophylactic antibiotics, and retraining the knowledge about prevention and treatment of contamination (Fig. 1). When PD patients developed contamination, they should stop dialysate exchange procedure and call medical staff immediately. Then, the medical staff estimated the type of contamination in detail. Dry contamination was defined as contamination outside a closed PD system, and wet contamination was defined as contamination with an open PD system [2, 3]. In cases of dry contamination, the patient was required only to replace the contaminated parts, such as dialysate bag, mini-cap, or catheter transfer set. In cases of wet contamination, the patient was instructed to clamp the PD catheter correctly. If the PD catheter was intact, the catheter transfer set was required to be replaced with a new one. If the distance from the broken position of the PD catheter to the exit site of skin was ≥5 cm, it needed to disinfect and cut off the broken part of the PD catheter, and connect the remaining PD catheter with titanium joint and new catheter transfer set. If the distance from the broken position of the PD catheter to the exit site of skin was <5 cm, prophylactic intravenous antibiotics should be used according to medical advice. Then, the dialysis effluent examination was evaluated. If the white blood cell count in the dialysis effluent was $<100 \times 10^6$/L and polymorphonuclear leukocytes in the dialysis effluent were <50%, one to three doses of intraperitoneal cefazolin 1 g and amikacin 100 mg were administered to prevent peritonitis. If the white blood cell count in the dialysis effluent was $\geq 100 \times 10^6$/L and polymorphonuclear leukocytes in the dialysis effluent were ≥50% and consistent with the diagnosis of PD-associated peritonitis, it needed to be treated as peritonitis. Finally, the characteristics of the PD catheter were assessed. If the PD catheter showed signs of wear, or denaturation, or the distance from the broken position of the PD catheter to the exit site of skin <5 cm, but the patient had adequate dialysis and normal peritoneal function, replacing the PD catheter was suggested. If the patient had insufficient dialysis or peritoneal ultrafiltration failure, changing to hemodialysis was deemed necessary. The patient accepted retraining in the course of treatment. The content of retraining was the same as that of the original training.

Data Collection

The patients' demographic information and treatment data regarding wet contamination were collected. Demographic information comprised the patient's age and sex, PD duration, primary renal disease, education level, annual income, requirement for assisted PD, self-care ability, and the distance from home to hospital. Treatment data comprised wet contamination type, treatment compliance, and reasons for non-compliance with the management algorithm. The definition of compliance with the management algorithm was that PD patients could identify wet contamination correctly, accept treatment in accordance with a standard management algorithm timely, and use prophylactic antibiotics according to medical advice. All patients were followed up for 1 month after wet contamination to detect peritonitis. Data for the pathogenic bacteria and treatment outcomes in cases of peritonitis were also collected. Wet contamination-associated peritonitis was defined as PD-associated peritonitis within 7 days of wet contamination [3]. The diagnosis of PD-associated peritonitis was based on at least two of the following criteria: (1) clinical features consistent with peritonitis, that is, abdominal pain and/or cloudy dialysis effluent; (2) dialysis effluent white blood cell count >100/μL or $>100 \times 10^6$/L (after a dwell time of at least 2 h), with >50% polymorphonuclear leukocytes; and (3) positive dialysis effluent culture [1]. For pathogen culture, 50 mL of dialysis effluent was centrifuged at 3,000 *g* for 15 min, and the pellet was inoculated in BacT/Alert anaerobic and aerobic bottles (bioMérieux, Durham, NC, USA). The Vitek-2 AutoMicrobic system (bioMérieux, St Louis, MO, USA) was used to determine all isolates and their susceptibilities to certain antibiotics.

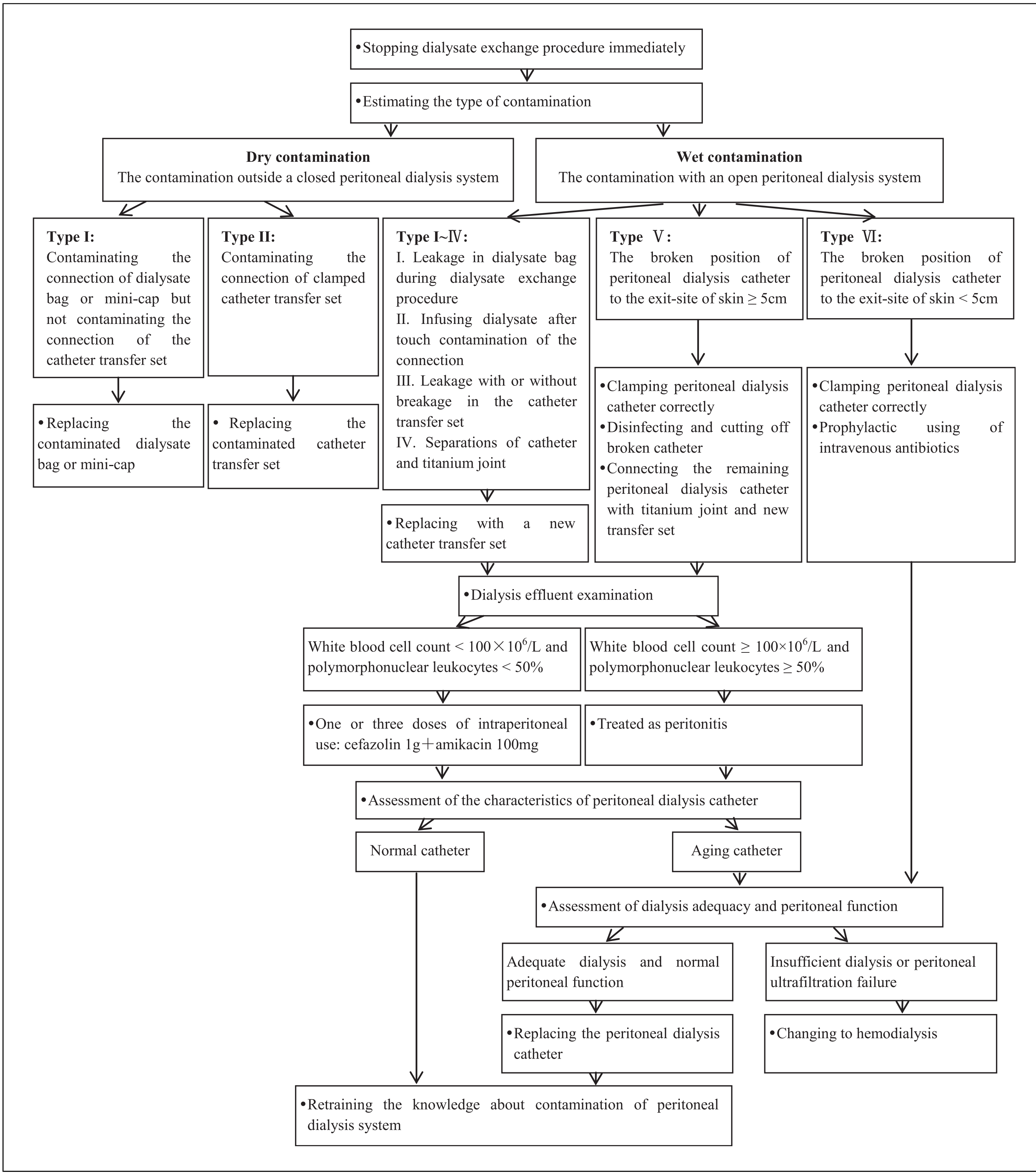

Fig. 1. Management algorithm for contamination of PD system.

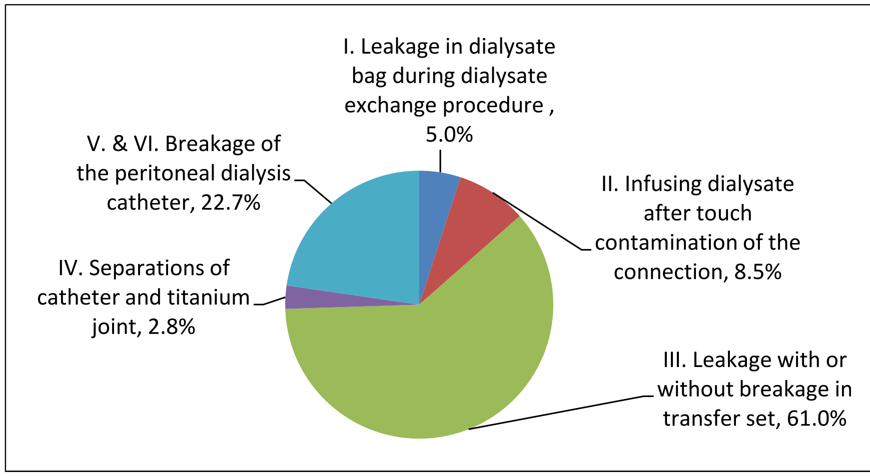

Fig. 2. The wet contamination types of PD system.

Statistical Analysis

SPSS software version 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Continuous variables with normal distribution were expressed as mean with standard deviation and compared by the independent sample *t* test. Continuous variables with non-normal distribution were expressed as median with interquartile range and compared by the Mann–Whitney U test. Categorical variables were expressed as frequency and percentage and compared using the χ^2 test. Binary logistic regression was used to analyze the influencing factors for treatment non-compliance of wet contamination. General loglinear analysis was used to analyze the risk factors for wet contamination-associated peritonitis. Differences were considered statistically significant with two-sided $p < 0.05$.

Results

Characteristics of Patients with Wet Contamination

During the study period, 148 cases with wet contamination were enrolled, of which 4 accepted treatments in other hospitals, 1 developed acute gastroenteritis simultaneously, 1 experienced cardiopulmonary arrest, and 1 accepted colonoscopic polypectomy simultaneously. Therefore, 141 cases of wet contamination were included in this study. The patients' mean age was 51.7 ± 14.1 years, and 49.6% were female. The primary renal diseases were glomerulonephritis (62.4%), diabetic nephropathy (9.9%), and hypertensive renal damage (10.6%). The median PD duration was 27.0 (1.7–79.7) months.

The main types of wet contamination were leakage with or without breakage in the catheter transfer set (61%), breakage of the PD catheter (22.7%), and infusing dialysate after touch contamination of the connection (8.5%) (Fig. 2). One hundred and six cases (75.2%) were treated in accordance with the contamination management algorithm. The remaining 35 cases did not comply with the contamination management algorithm, among which 21 cases (60.0%) infused dialysate after leakage, or breakage, or touch contamination of the PD system, 9 (25.7%) did not consent to receive prophylactic antibiotics, and 5 (14.3%) were not treated wet contamination in time. Compared with the compliance with the management algorithm group, the non-compliance with the management algorithm patients were older and had longer PD duration (all, $p < 0.05$) (Table 1). Binary logistic regression analysis showed that advanced age and longer distance from home to hospital were independently associated with the treatment non-compliance for wet contamination after adjusting for all other confounders (all, $p < 0.05$) (Table 2).

Influencing Factors for Wet Contamination-Associated Peritonitis

After wet contamination, there were 18 episodes (12.8%) of peritonitis. The incidence of peritonitis in the compliance with the management algorithm group was significantly lower than that in the non-compliance with the management algorithm group (1 episode, 0.9% vs. 17 episodes, 48.6%, respectively; $p < 0.001$). The pathogenic bacteria in the cases of peritonitis were Gram-positive bacteria (6 episodes [33.3%]: 3 episodes of *Staphylococcus*, 2 episodes of *Streptococcus*, and 1 episode of *Kocuria rhizophila*), Gram-negative bacteria (5 episodes [27.8%]: 3 episodes of *Escherichia coli* and 2 episodes of *Acinetobacter baumannii*), mixed infection (2 episodes, 11.1%), and negative bacterial culture (5 episodes, 27.8%). Seventeen episodes of peritonitis were cured, and 1 patient was changed to hemodialysis. Univariate

Table 1. Comparison of demographic characteristics between compliance with management algorithm group and non-compliance with management algorithm group

Variables	Total (*n* = 141)	Compliance group (*n* = 106)	Non-compliance group (*n* = 35)	*p* values
Age, years	51.7±14.1	50.3±14.0	56.2±13.4	0.031
Sex (female)	70 (49.6%)	53 (50.0%)	17 (48.6%)	0.883
PD duration, months	27.0 (1.7–79.7)	15.3 (1.0–72.6)	54.6 (5.4–101.5)	0.039
Primary renal diseases, *n* (%)				0.533
Glomerulonephritis	88 (62.4)	68 (64.2)	20 (57.1)	
Diabetic nephropathy	14 (9.9)	10 (9.4)	4 (11.4)	
Hypertensive renal damage	15 (10.6)	9 (8.5)	6 (17.1)	
Other	24 (17.1)	19 (17.9)	5 (14.3)	
Accepting 9 years of education, *n* (%)	118 (83.7)	92 (86.8)	26 (74.3)	0.083
Annual income, *n* (%)				0.603
<10,000 yuan	24 (17.0)	16 (15.1)	8 (22.9)	
10,000–29,999 yuan	23 (16.3)	20 (18.9)	3 (8.6)	
30,000–49,999 yuan	33 (23.4)	25 (23.6)	8 (22.9)	
50,000–99,999 yuan	31 (22.0)	26 (24.5)	5 (14.3)	
≥100,000 yuan	30 (21.3)	19 (17.9)	11 (31.4)	
Self-care, *n* (%)	131 (92.9)	98 (92.5)	33 (94.3)	0.714
Assisted PD, *n* (%)	23 (16.3)	17 (16.0)	6 (17.1)	0.878
Distance from home to hospital, km	42.3 (10.7–212.0)	31.0 (10.2–150.4)	103.8 (15.4–344.8)	0.084

Table 2. Influencing factors for the treatment non-compliance with wet contamination of PD system

Variables	Univariate binary logistic regression analysis			Multivariate binary logistic regression analysis		
	OR	95% CI	*p* values	OR	95% CI	*p* values
Age (per 1 year)	1.031	1.002–1.061	0.034	1.040	1.004–1.076	0.027
Sex (female)	0.944	0.440–2.028	0.883	1.222	0.534–2.800	0.635
PD duration (per 1 month)	1.006	0.998–1.013	0.133	1.004	0.996–1.012	0.377
Distance from home to hospital (per 1 km)	1.002	1.000–1.004	0.085	1.003	1.000–1.005	0.046
Accepting 9 years of education (yes)	0.440	0.171–1.130	0.088	0.563	0.197–1.611	0.284
Self-care (yes)	1.347	0.272–6.664	0.715	4.574	0.718–29.161	0.108

OR, odds ratio; 95% CI, 95% confidence interval.

general loglinear analysis showed that advanced age, longer distance from home to hospital, and non-compliance with the management algorithm were associated with wet contamination-associated peritonitis (all, $p < 0.05$). After adjusting for these variables, with sex and PD duration, multivariate general loglinear analysis showed that non-compliance with the management algorithm, advanced age, and longer distance from home to hospital were independent risk factors for wet contamination-associated peritonitis (all, $p < 0.05$) (Table 3).

Discussion

The present study showed that the incidence of wet contamination-associated peritonitis was 12.8% in wet contamination cases. The main pathogenic bacteria in cases of peritonitis were Gram-positive bacteria and Gram-negative bacteria. The incidence of peritonitis in the compliance with the management algorithm group was significantly lower than that in the non-compliance with the management algorithm

Table 3. Risk factors for wet contamination-associated peritonitis

Variables	Univariate general loglinear analysis			Multivariate general loglinear analysis		
	OR	95% CI	*p* values	OR	95% CI	*p* values
Age (per 1 year)	1.047	1.011–1.084	0.010	1.116	1.071–1.163	<0.001
Sex (female)	1.019	0.405–2.568	0.968	1.251	0.434–3.604	0.678
PD duration (per 1 month)	1.001	0.992–1.010	0.784	0.990	0.980–1.000	0.057
Distance from home to hospital (per 1 km)	1.004	1.002–1.007	<0.001	1.007	1.005–1.010	<0.001
Non-compliance with management algorithm (yes)	80.399	10.708–603.653	<0.001	185.861	23.524–1,468.505	<0.001

OR, odds ratio; 95% CI, 95% confidence interval.

group. Non-compliance with the management algorithm, advanced age, and longer distance from home to hospital were independent risk factors for wet contamination-associated peritonitis.

The incidence of wet contamination-associated peritonitis was 12.8% in the present study, which was higher than that reported in a previous study (5.63%) [3]. The main reason might be that the episodes of peritonitis were mainly concentrated in the non-compliance with the management algorithm group in the present study. The main pathogenic bacteria associated with peritonitis in this study were Gram-positive bacteria (33.3%) and Gram-negative bacteria (27.8%). A previous study showed that the main pathogenic bacteria in wet contamination-associated peritonitis were *Staphylococcus* (35.3%), *A. baumannii* (17.6%), and *Pseudomonas aeruginosa* (11.8%) [3]. Therefore, it is essential to use prophylactic antibiotics that are effective against both Gram-positive and Gram-negative bacteria after wet contamination [1–3, 5]. In a previous study, prophylactic oral levofloxacin 250–300 mg daily for 3 days was effective in reducing episodes of peritonitis after wet contamination [3]. The 2016 peritonitis guideline of the International Society of Peritoneal Dialysis recommended a 2-day course of oral antibiotics for PD patients who infused contaminated dialysate into the peritoneal cavity [2]. In our management algorithm, one to three doses of prophylactic intraperitoneal cefazolin 1 g and amikacin 100 mg were administered to PD patients after wet contamination. This prophylactic antibiotic regimen was a simplified version of an empiric antibiotic regimen for peritonitis reported in the guideline [2]. Intraperitoneal administration was chosen because of its simple administration and fast drug absorption. The doses of prophylactic antibiotics depended on these factors including the exposure time to wet contamination, previous peritonitis episodes, exit-site infection, gastrointestinal inflammation, and PD duration. This regimen not only avoids the potential problem of habitual misuse of antibiotics [2], but also reduces toxicity and other adverse effects of antibiotics. Short-term aminoglycoside therapy is associated with minimal vestibular toxicity and does not accelerate the loss of residual renal function [6]. Through prospective observation, our results showed that the incidence of wet contamination-associated peritonitis in the compliance with the management algorithm group was 0.9%, which was lower than the incidence of 5.63% reported in the literature [3]. Moreover, only 1 patient with peritonitis was changed to hemodialysis. These results indicate that our management algorithm for wet contamination could reduce the risk of wet contamination-associated peritonitis.

Our results showed that non-compliance with the management algorithm, advanced age, and longer distance from home to hospital were independent risk factors for wet contamination-associated peritonitis. A previous study showed that long PD duration was associated with non-compliance [7]. Our results also showed that the non-compliance with the management algorithm group had longer PD duration. After a period of home PD treatment, some PD patients began to take shortcuts, modified the standard dialysate exchange procedure, and failed to follow sterile technique and hand hygiene protocols [8–10]. Non-compliance with the dialysate exchange procedure is significantly associated with the episodes of peritonitis [9, 11]. Therefore, retraining should target PD patients who have begun to take shortcuts or simply deviated from the standard steps that were taught previously [1]. Compared with younger PD patients, elderly PD patients often had more comorbidities, greater risk of cognitive impairment, higher degree of frailty, and potential sensory impairment [12]. Our previous study found that pre-existing frailty and cognitive impairment increased the risk of peritonitis in

PD patients [13]. Therefore, elderly frail PD patients required retraining to overcome many of the above obstacles [1, 2, 12]. When they have poor health conditions, caregivers must help them complete dialysate exchange procedure to reduce the occurrence of contamination. PD patients living outside a major city required more travel time to the hospital. The long exposure time to wet contamination might increase the risk of peritonitis. In addition, considering the long travel time, some PD patients might avoid trouble and continue dialysate exchanges without treatment. This incorrect operation also increased the risk of peritonitis. Our previous study suggested that poor compliance with regular visits to the nephrologist predicted adverse outcomes of remote PD patients [14]. Remote service can provide regular and effective communication between medical staff and patients, which may increase treatment compliance [15] and improve access to treatment and timely care [16].

We found that breakage of the PD catheter was a special type of wet contamination. It might require some additional treatment measures. If the distance from the break in the PD catheter to the exit site of skin was <5 cm, the remaining section of the PD catheter was too short to connect to the titanium joint; therefore, the PD catheter needed to be replaced. Long-term PD catheters are associated with a high prevalence of linear tears [17] or extensive microbial colonization [18]. Aging silicone rubber catheters must be replaced early because aging might jeopardize the catheter's bacteriological safety and increase the risk of peritonitis [19].

The advantages of this study were as follows: a detailed and referable management algorithm for wet contamination was developed in accordance with related literature and clinical practice. The effect of the clinical application of the management algorithm was observed to provide a clinical basis for reasonable treatment of wet contamination. There were also some limitations in this study. Peritonitis was a rare event. When exploring the impact of non-compliance with wet contamination management algorithm on wet contamination-associated peritonitis, small sample size and single-center study design might be the reasons for the bias. We will further expand the sample size to observe the effectiveness of wet contamination management algorithm in the future.

In conclusion, our management algorithm for wet contamination of PD system might reduce the risk of wet contamination-associated peritonitis. Non-compliance with the management algorithm, advanced age, and longer distance from home to hospital were independent risk factors for wet contamination-associated peritonitis. Correct identification of wet contamination, timely treatment in accordance with a standard management algorithm, and prophylactic antibiotics effective against both Gram-positive and Gram-negative bacteria are recommended for the treatment of wet contamination.

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Statement of Ethics

This study protocol was reviewed and approved by the Ethics Committee of the First Affiliated Hospital of Sun Yat-sen University, Approval No. (Ethical Review [2016] 215). This study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants included in the study.

Conflict of Interest Statement

All authors declare no conflicts of interest. The results presented in this article have not been published previously in whole or part, except in abstract format.

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Author Contributions

All authors have contributed significantly in keeping with the latest guidelines of the International Committee of Medical Journal Editors, and read and approved the final manuscript. Xiao Yang, Chunyan Yi, and Wenbo Zhang conceived and designed the study. Chunyan Yi and Jianxiong Lin prepared and performed data collection. Chunyan Yi and Wenbo Zhang analyzed the data, interpreted the results, and drafted the manuscript. Xiao Yang, Qunying Guo, Wei Chen, and Haiping Mao coordinated the study and finally approved the version to be published.

Data Availability Statement

The data that support the findings of this study are not publicly available due to their containing information that could compromise the privacy of research participants, but are available from the corresponding author Xiao Yang upon reasonable request.

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