

Peritoneal Dialysis–Associated Peritonitis: Suggestions for Management and Mistakes to Avoid



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Peritonitis is a common complication of peritoneal dialysis that is associated with substantial morbidity and mortality. Peritonitis increases treatment costs and hospitalization events and is the most common reason for transfer to hemodialysis. Although there is much focus on preventing peritoneal dialysis–associated peritonitis, equally as important is appropriate management to minimize the morbidity of a peritonitis episode when it has occurred. Despite the presence of international guidelines on peritonitis treatment, the evidence base to support optimal peritonitis treatment practices is lacking, leaving the practitioner to rely on clinical experience and extrapolate from across other infection treatment practices. This article reviews common mistakes and misconceptions that we have observed in the management of peritonitis that may compromise treatment success. It also provides suggestions on common controversial aspects of peritonitis management based on the best available literature. Although the use of the word mistakes is somewhat controversial and subjective, we acknowledge that evidence is lacking and have based many of our suggestions on clinical judgment, experience, and available data.

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INTRODUCTION

Peritoneal dialysis (PD)–associated peritonitis is associated with substantial morbidity, contributing to death in up to 8.6% of patients.¹ Peritonitis increases treatment costs and hospitalization events and is a primary reason for transition to hemodialysis (HD).²⁻⁴ PD-related infection has been identified as a core outcome of critical importance in the multistakeholder SONG (Standardised Outcomes in Nephrology) PD initiative.⁵

Despite International Society for Peritoneal Dialysis (ISPD) guidelines on peritonitis treatment, variability exists in the diagnosis and management of peritonitis among PD centers worldwide, with limited uptake of these recommendations.⁶ Overall peritonitis treatment failure rates are as high as 25%.^{7,8} Although many studies have focused on peritonitis prevention, more effort needs to be focused on successful management.

By addressing mistakes and misconceptions in the management of peritonitis that can compromise treatment success, we hope to improve peritonitis outcomes. It is important to note that there are areas in peritonitis management in which evidence is weak or lacking, meaning that we rely on clinical judgment and extrapolate from the infectious disease literature. The following are 10 suggestions and possible mistakes to avoid in the management of patients with peritonitis (Box 1).

1. WE WAIT TOO LONG TO GIVE ANTIBIOTICS AND FOCUS TOO MUCH ON THE ROUTE

Early initiation of antibiotic therapy leading to improved patient survival has been well studied in the infectious disease literature.^{9,10} Because prompt initiation of antibiotic therapy for peritonitis also is critical, the ISPD

recommends that empirical treatment be started as soon as peritonitis is suspected.¹¹

The relationship between the timing of antibiotic administration in peritonitis and PD-related outcomes was studied by Muthucumarana et al¹² in a prospective multicenter study of 116 patients with 159 episodes of peritonitis in Western Australia. The 3 main time measurements were symptom-to-contact time (contact to medical or nursing personnel), contact-to-treatment time, and symptom-to-treatment time (the sum of both). The outcome for each peritonitis episode was resolution of peritonitis at 30 days and PD failure, which was defined as either catheter removal or death at 30 days. Thirty-eight patients had PD failure at 30 days (28 catheter removals and 10 deaths). Contact-to-treatment time was independently associated with PD failure, and risk for PD failure increased by 5.5% for each hour of delay of administration of antibiotics.

The ISPD recommends the intraperitoneal (IP) route in the administration of antibiotics unless features of systemic sepsis are present. The evidence supporting the superiority of the IP route was based on only 1 study. In that study, Bennett-Jones et al¹³ reported 75 patients with peritonitis who were randomly assigned to receive either IP or intravenous (IV) vancomycin and tobramycin. An increase was observed in the primary treatment failure rate for IV versus IP vancomycin and tobramycin (risk ratio, 3.52; 95% confidence interval, 1.26-9.81).¹³ The advantages of the IP route are delivering a high concentration of antibiotics to the peritoneum, avoidance of IV access, and the possibility of home antibiotic administration by trained patients. However, antibiotic administration delays may be related to the IP route, particularly in emergency departments and wards in which PD-trained staff are not

Box 1. Summary of Suggestions for Management and Mistakes to Avoid

1. We wait too long to give antibiotics and focus too much on the route
2. We do not consider antifungal prophylaxis
3. We might be collecting and interpreting the PD effluent cell count incorrectly
4. We do not dose and choose antibiotics correctly
5. We remove the PD catheter too quickly or not quickly enough
6. Not all abdominal pain and cloudy effluent is peritonitis
7. We do not consider return to PD after catheter removal
8. We do not perform quality improvement and talk to our microbiology laboratory
9. We do not consider simultaneous PD catheter removal and reinsertion
10. Not all peritonitis is PD peritonitis

Abbreviation: PD, peritoneal dialysis.

readily available to attend to the patients quickly. In such case, using the IV route for faster administration should be considered. However, the efficacy of different IV antibiotics in PD peritonitis needs further evaluation and study. Although some centers provide patients with IP antibiotics to keep at home for prompt administration when the symptoms are recognized by the patient, the benefit of this approach should be weighed against the possibility of increasing the risk for culture-negative peritonitis by inadvertently initiating antibiotic therapy before PD effluent culture. This can be obviated by having the patient collect and refrigerate the effluent sample before antibiotic initiation.

2. WE DO NOT CONSIDER ANTIFUNGAL PROPHYLAXIS

Prior antibiotic therapy for peritonitis (or any other indication) is a known risk factor for fungal peritonitis. This is possibly the result of the disruption of normal bowel flora by the antibiotics, which promote enteric fungal overgrowth.¹⁴⁻¹⁷ The ISPD recommends antifungal prophylaxis to prevent fungal peritonitis when PD patients receive antibiotics (evidence level 1B).¹¹ This is particularly important in immunocompromised patients and those receiving broad-spectrum antibiotics for longer duration because these are additional risk factors for fungal peritonitis. **Table 1** summarizes the studies of the effectiveness of fungal prophylaxes on incidence of fungal peritonitis.

In the Peritoneal Dialysis Outcomes and Practice Patterns Study (PDOPPS), substantial variation was observed in the use of antifungal prophylaxis during antibiotic therapy among participating centers. In Australia and New Zealand, for instance, 89% of the centers used antifungal prophylaxis compared with 54% in the United States and only 8% in Japan.⁶ Of note, consideration for fungal prophylaxis practice needs to be taken in the context of

Table 1. Fungal Peritonitis Without and With Prophylaxis While Receiving Antibiotics

Incidence of Fungal Peritonitis, episodes/y	Prophylaxis	Reference
0.29 vs 0.02	Nystatin 3×/d	Zaruba et al. <i>Am J Kidney Dis.</i> 1991;17:43-46
0.17 vs 0	Nystatin or ketoconazole	Robitaille P. <i>Perit Dial Int.</i> 1995;15:77-79
0.08 vs 0.01	Fluconazole QOD	Wadhwa et al. <i>Adv Perit Dial.</i> 1996;12:189-191
0.02 vs 0.01	Nystatin 4×/d	Lo et al. <i>Am J Kidney Dis.</i> 1996;28:549-552
0.02 vs 0.02	Nystatin 4×/d	Thodis et al. <i>Perit Dial Int.</i> 1998;18:583-589
0.01 vs 0.01	Nystatin 4×/d	Williams P, et al. <i>Perit Dial Int.</i> 2000;20:352-353

Abbreviation: QOD, every other day.

individual countries and centers because the utility of this approach might be lower in centers with low rates of fungal peritonitis. The preferred agent in our opinion is nystatin, given the low cost and safety profile with a dose of 500,000 units orally 4 times per day for the entire duration of antibiotic therapy plus 1 week. In centers and countries in which nystatin is not available, fluconazole can be used at a dose of 200 mg every 48 hours. Systemic side effects, drug interactions, and the development of resistant strains are major concerns that need to be considered when prescribing fluconazole.

3. WE MIGHT BE COLLECTING AND INTERPRETING THE PD EFFLUENT CELL COUNT INCORRECTLY

Peritonitis is defined by the presence of at least 2 of the following: (1) clinical features consistent with peritonitis (eg, abdominal pain and/or cloudy dialysis effluent); (2) dialysis effluent white blood cell (WBC) count > 100 cells/ μL or $>0.1 \times 10^9$ cells/L, with >50% polymorphonuclear leukocytes (PMNs); and (3) positive effluent culture.

It is important to note that the WBC count in the effluent is dependent on the dwell time and an appropriate dwell time is at least 2 hours. The short dwell in automated PD (APD) patients with rapid cycles may not be enough time to mount a cell count. In this case, the percentage of PMNs can be more reliable because a proportion > 50% of PMNs is strong evidence of peritonitis, even if the absolute WBC count is $<100/\mu\text{L}$.¹¹ Tuberculous peritonitis usually also presents with a higher effluent neutrophil count, although cases with effluent lymphocyte predominance have been reported.^{18,19}

In the absence of clinical features suggestive of peritonitis (abdominal pain and/or cloudy dialysate), routine effluent culture is discouraged, resulting in unnecessary treatment if positive in the face of a normal effluent cell count. If PD effluent cultures are persistently positive with a normal effluent cell count, it is important to consider bacteremia with secondary peritoneal seeding, possible

early peritonitis, or colonization/infection of the PD catheter. Only if persistently positive, we would recommend treatment even in the absence of peritoneal effluent leukocytosis.

4. WE DO NOT DOSE AND CHOOSE ANTIBIOTICS CORRECTLY

Dual antibiotic regimens are recommended for empiric peritonitis treatment and include vancomycin or a first-generation cephalosporin to cover Gram-positive organisms and a third-generation cephalosporin or an aminoglycoside to cover Gram-negative organisms (including antipseudomonal activity). Given that vancomycin, most cephalosporins, and aminoglycoside are excreted by the kidneys, patients with significant residual kidney function will have more clearance of the antibiotics and therefore lower concentrations in the blood and peritoneum.

The importance of dosing the antibiotics on the basis of the degree of residual kidney function was supported by an observational study of 181 patients with 339 episodes of Gram-positive, Gram-negative, and culture-negative peritonitis. Episodes were categorized according to patients' urinary creatinine clearances (0, 0-5, and >5 mL/min). In patients with greater residual kidney function, the risk for treatment failure, relapse, and recurrent peritonitis for Gram-positive or culture-negative peritonitis was significantly higher compared with anuric patients.²⁰

Another important antibiotic-dosing consideration is PD modality (APD vs continuous ambulatory PD [CAPD]). Although APD is the most common PD modality across many high-income countries, pharmacokinetic and dosing data for IP antibiotics and in particular cephalosporins remain limited because most studies have been conducted in CAPD patients. Extrapolation of antibiotic pharmacokinetic data from CAPD to APD may be misleading due to greater peritoneal antibiotic clearance in APD compared with CAPD, possibly resulting in subtherapeutic antibiotic levels. In some circumstances, switching APD patients to CAPD may ensure adequate levels of antibiotics.²¹ In addition, if antibiotics need to be given continuously, APD will need to be switched to CAPD. In our center, we switch APD patients with ampicillin-sensitive *Enterococcus* peritonitis to CAPD to facilitate ampicillin dosing, which must be dosed continuously.

Given that maintaining a therapeutic antibiotic concentration is an important factor in the treatment of peritonitis, antibiotics such as vancomycin, if given during peritonitis treatment, should be measured and kept at >15 µg/mL. An accepted dosing interval to achieve such level is every 4 to 5 days. Although some centers may give vancomycin on a daily basis using lower doses, this approach might be impractical and less cost-effective. A randomized controlled trial in children demonstrated that intermittent dosing of vancomycin is as efficacious as continuous dosing.²² However, it is important to note that patients with substantial residual kidney function or

patients receiving APD will likely have greater antibiotic clearance and require more frequent dosing.^{23,24} The relationship between peritonitis relapse rates and vancomycin trough levels was investigated in a retrospective analysis of 31 episodes of Gram-positive peritonitis by Mulhern et al.²⁵ Patients who had a cumulative 4-week trough serum vancomycin level < 12 mg/L or an initial 7-day trough serum level < 9 mg/L had significantly higher risks for peritonitis relapse.²⁵ In another study by Dahlan et al²⁶ of 35 episodes of coagulase-negative *Staphylococcus* species peritonitis, the mean trough vancomycin concentration was lower in patients who experienced relapse compared with those who did not (13.3 vs 18.2 mg/L).

Another controversial area is whether dosing of IP antibiotics in every exchange is more efficacious than intermittent (in 1 daily exchange) dosing. Some studies have shown that intermittent dosing of IP vancomycin and gentamicin is as effective as continuous dosing in CAPD patients.^{22,27,28} Although in our center we use intermittent dosing of IP ceftazidime, 2 pharmacokinetic studies demonstrated that a once-daily IP administration of ceftazidime at a dose of 15 to 20 mg/kg can result in subtherapeutic blood levels. To achieve a therapeutic level of ceftazidime, a recommended loading dose of 3 g with maintenance dosing of 1 to 2 g every 24 hours is suggested. It is important to note that in both studies, there were no data for residual kidney function.^{29,30}

Extended-spectrum β-lactamase organisms are an emerging concern in Gram-negative PD peritonitis and carry higher treatment failure and mortality rates.^{31,32} Although these organisms might be sensitive to cephalosporin and aminoglycosides at the outset, they often become resistant to those antibiotics but remain sensitive to carbapenems in most cases. There are few data for the efficacy of IP carbapenems in peritonitis patients. Few case reports have suggested that meropenem is effective and safe when given IP.^{33,34}

When treating *Pseudomonas* peritonitis, double antibiotic coverage for this organism should be considered. *Pseudomonas* species are usually difficult to treat and are associated with higher rates of concomitant exit-site and tunnel infection, hospitalization, catheter removal, and technique failure.^{4,35,36} To improve the outcomes of such infection, the 2016 update of the ISPD guidelines for management of PD-related infections recommends using dual antibiotic therapy with different mechanisms of action and to which the organism is sensitive. This includes either gentamicin or oral ciprofloxacin with ceftazidime or cefepime for 3 weeks.¹¹ In a large observational study from the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA), episodes caused by *Pseudomonas* species that were treated with dual antipseudomonal agents were significantly less likely to be complicated by the need for permanent HD transfer than those that did not receive such treatment (10% vs 38%, respectively; $P = 0.03$). No significant difference was observed with respect to relapse,

catheter removal, and death rates.³⁶ If oral ciprofloxacin is given, it should be separated from oral iron and phosphate binders to maximize absorption or in many cases, the latter medications can be temporarily withheld while on antibiotic treatment.

5. WE REMOVE THE PD CATHETER TOO QUICKLY OR NOT QUICKLY ENOUGH

The indications for PD catheter removal are refractory peritonitis, relapsing peritonitis, refractory exit-site and tunnel infection, and fungal peritonitis. Catheter removal should also be considered in the case of repeat peritonitis, mycobacterial peritonitis, and multiple enteric organisms.¹¹

Fungal peritonitis carries high rates of hospitalization, technique failure, and death.^{14,37,38} Immediate catheter removal is recommended by the ISPD when fungi are identified in PD effluent in the face of effluent leukocytosis, no matter the clinical status of the patient.¹¹ Observational studies have demonstrated that prompt catheter removal in fungal peritonitis improves outcomes and reduces mortality. In a large single-center study by Chang et al,³⁸ the effect of immediate catheter removal on mortality in PD patients was investigated in 94 episodes of fungal peritonitis in 92 patients. The mortality rate of fungal peritonitis in this study was 28.7%, with a 21-day median duration between the diagnosis of fungal peritonitis and death. The PD catheter was removed within 24 hours in 39 patients and between 2 and 9 days after the diagnosis in 42 patients. Delayed catheter removal (after 24 hours from the diagnosis of fungal peritonitis) was an independent predictor for fungal peritonitis–related mortality (31.7% vs 12.8%).³⁸

The ISPD recommends removing the PD catheter in case of refractory peritonitis, which is defined as failure of the PD effluent to clear after 5 days of appropriate antibiotic treatment. This approach of using a 5-day cutoff may lead to unnecessary or premature catheter removal given the lack of evidence on its effect on long-term outcomes compared with a longer wait. Although infectious disease consultants often advocate for early and more aggressive catheter removal as “source control,” in our opinion, the decreasing trajectory of the effluent WBC count should allow for more than 5 days of treatment before the catheter is removed, particularly in the face of less virulent organisms such as coagulase-negative staphylococci. This may even be applied in the case of peritonitis caused by *Pseudomonas* species. There is a misperception that the catheter should be removed early in the course of the infection. However, a trial of therapy should be allowed because a significant proportion of these infections can be successfully treated with antibiotics. The exception to this approach would be if there was a concomitant pseudomonal or *Staphylococcus aureus* exit-site or tunnel infection, in which case it is assumed that the catheter itself is infected or colonized with the organism and should be removed.

6. NOT ALL ABDOMINAL PAIN OR CLOUDY EFFLUENT IS PERITONITIS

Although abdominal pain is a common presenting symptom of peritonitis, other causes should not be overlooked. These include but are not limited to ischemic colitis, pancreatitis, pyelonephritis, ruptured ovarian or kidney cyst, transplant kidney rejection, *Clostridium difficile* infection, and strangulated/incarcerated hernia. Another component of peritonitis definition is cloudy effluent, which can also be nonspecific for peritonitis because it can be the result of various noninfectious causes such as eosinophilic peritonitis, hemoperitoneum, malignancy, chylous effluent, and sampling fluid from a dry abdomen or from a dwell with an extended time.³⁹

Analysis of the effluent cells can provide clues toward the cause. Eosinophilic peritonitis for instance presents with cloudy effluent with an elevated eosinophilic count (typically 10%–30%). This typically occurs within the first weeks of PD initiation and can be the result of an allergic reaction to the PD solutions, plasticizers, tubing, air, vancomycin, streptokinase, or the PD catheter itself.^{40–45} Effluent eosinophilia can be associated with concomitant elevation of peripheral-blood eosinophilia.^{46–48} Eosinophilic peritonitis usually resolves spontaneously, although it can take several months. Use of antihistamines or low-dose corticosteroid therapy may be helpful.^{40,42,49–51}

Cytology and possibly flow cytometry should be ordered in cases of recurrent sterile cloudy effluent to rule out malignant cells in the dialysate. Although rare, cases of lymphoma and peritoneal metastasis presenting with cloudy effluent and malignant cells in the cytologic analysis of the effluent have been reported.^{52–55} In cases of milky white effluent, checking triglyceride levels can be helpful because chylous effluent is typically noncellular and rich in triglycerides (higher dialysate levels compared with serum). It may wax and wane relating to dietary fat intake. Lymphatic obstruction secondary to lymphoma is another cause of chylous effluent.⁵⁶ Acute pancreatitis,⁵⁷ certain calcium channel blockers,⁵⁸ superior vena cava syndrome,⁵⁹ and trauma to the lymphatics following PD catheter insertion are additional causes.⁶⁰

7. WE DO NOT CONSIDER RETURN TO PD AFTER CATHETER REMOVAL

Following severe peritonitis that necessitates PD catheter removal and regardless of the responsible organism, approximately 30% to 50% of patients could potentially return to PD.^{61–64} The ISPD suggests that it is appropriate to consider return to PD following catheter removal for refractory, relapsing, or fungal peritonitis. Using ANZ-DATA, Cho et al⁶⁵ demonstrated that return to PD following temporary HD was not associated with inferior clinical outcomes compared with patients who either never required HD or stayed permanently on HD after peritonitis. In an observational study from Hong Kong,

Table 2. Root Cause Analysis by Causative Organism

Organism	Possible Cause	Action
Coagulase-negative staphylococcal species and <i>Staphylococcus aureus</i>	Breaks in sterile technique during connection; exit-site infection	Patient retraining; exit-site care; transfer set exchange; consider biofilm infection in relapse or repeat peritonitis
<i>Streptococcus</i>	Dental procedures; GI flora translocation	Review protocols for dental and endoscopic procedures prophylaxis; examination for and treatment of dental and periodontal disease
Enteric organisms (Gram-negative rods and anaerobes)	Intra-abdominal pathology; severe constipation/GI procedures	Avoid constipation; antibiotic prophylaxis for endoscopic procedures; if multiple organisms, consider CT
Fungus	Prior antibiotic therapy/immunocompromised state	Consider antifungal prophylaxis for antibiotic courses
<i>Pseudomonas aeruginosa</i>	Exit-site and tunnel infection	Review protocols for exit-site and catheter care
<i>Pasteurella</i> species	Domestic pets, mainly cats	Patient education on avoiding the pets during exchanges and exit-site care; hand hygiene
Culture negative	Prior antibiotic therapy; suboptimal culturing techniques	Review culturing methods and specimen handling; ask about antibiotic exposure; if unresolving, consider unusual organisms (ie, TB)

Abbreviations: CT, computed tomography; GI, gastrointestinal; TB, tuberculous.

100 patients with 108 episodes of peritonitis that required catheter removal and temporary HD between 1995 and 2000 were analyzed. All patients had an attempted Tenckhoff catheter reinsertion at least 4 weeks after the initial catheter was removed; 51 of 100 patients had successful catheter reinsertion with resumption of PD, whereas for the remaining 49, catheter reinsertion was attempted but failed, mainly because of significant peritoneal sclerosis and bowel adhesions. The group with failed catheter reinsertion had a higher proportion of fungal peritonitis compared with patients with successful PD catheter reinsertion (16% vs 4%) and were of longer dialysis vintage (41 ± 29 vs 29.7 ± 17 months).⁶³

Taken together, it is important to consider the overall clinical picture of the patient before peritonitis before making a decision to return to PD and to allow for shared decision making after explaining the risks and benefits of PD return. In our centers, we always discuss with patients that in some cases of fungal or severe peritonitis, the extent of the adhesions may not make it possible to return to PD.

There is no evidence on the optimal time between catheter removal for peritonitis and reinsertion of a new one. A few observational studies suggest a minimum of 2 to 3 weeks.^{63,64} Surgical advanced laparoscopic reinsertion is preferred over approaches that do not allow for direct visualization and lysis of potential adhesions.

8. WE DO NOT PERFORM QUALITY IMPROVEMENT AND TALK TO OUR MICROBIOLOGY LABORATORY

Each PD center should have a continuous quality improvement program in place to reduce peritonitis rates.¹¹ The impact of such programs on the reduction of peritonitis is well demonstrated.⁶⁶⁻⁶⁸ The continuous quality improvement team should investigate and identify the root cause of every single peritonitis episode to plan interventions to

prevent further episodes. Such interventions may include patient retraining, applying new protocols for exit-site care, prophylaxis for dental or endoscopic procedures, and management protocols for dry and wet contamination. It is important to note as well that the responsible organism for peritonitis can often provide a clue to the cause (Table 2). For instance, coagulase-negative staphylococci are often related to contamination during connection and hence reviewing patient technique and retraining are critical.

Reducing rates of culture-negative peritonitis is another important role of a continuous quality improvement team. A rate < 10% is ideal and can be achieved in experienced centers.¹¹ The main 2 modifiable causes of culture-negative peritonitis are antibiotic administration before effluent culture and suboptimal culture techniques and specimen handling. In a retrospective study, 212 consecutive episodes of culture-negative peritonitis in 149 patients in Hong Kong during a 6-year period were analyzed. Approximately 26.4% had a history of antibiotic therapy within 30 days before the onset of peritonitis, and in 109 episodes of peritonitis for which effluent culture was obtained by a trained renal nurse, 11.6% had negative culture results compared with 56.5% when performed by nurses in general medical wards.⁶⁹ In a single-center experience aiming to reduce rates of culture-negative peritonitis, Kocyigit et al⁷⁰ demonstrated a significant reduction (from 40.5% to 18.8%) over 7 years following improvement in culturing techniques. Of note, culture-negative rates might be higher when patients with suspected peritonitis go to emergency departments, given the variability in culturing technique compared with PD units. However, it is not always possible to have patients come to the PD unit because many home dialysis units do not have weekend call facilities. To improve the culture yield, the ISPD suggests the following: sending the specimens to the laboratory within 6 hours of sampling, direct bedside inoculation of 5 to 10 mL of effluent into 2 rapid (aerobic

and anaerobic) blood-culture bottle kits, and centrifugation of 50 mL of PD fluid at 3,000g for 15 minutes and resuspending the sediment in 3 to 5 mL of buffer for culturing.¹¹ It is important to ensure that the PD care team and microbiology laboratory are aware of these steps when processing PD effluent samples.

9. WE DO NOT CONSIDER SIMULTANEOUS PD CATHETER REMOVAL AND REINSERTION

When catheter removal and subsequent reinsertion is indicated, the standard procedure consists of 2 stages: removal of the PD catheter and subsequent reinsertion of a new catheter after an interval of peritoneal rest and antibiotics. This undefined period usually requires temporary transfer to HD, often using a central venous catheter. The advantages of simultaneous catheter replacement include the following: decreasing unplanned transfer to HD, maintaining patient preference regarding dialysis modality, and avoiding the complications that might result from temporary HD transfer, such as central venous catheter infections and rapid decline in residual kidney function.

The feasibility of a 1-step strategy of simultaneously removing and reinserting the PD catheter in select cases of peritonitis was investigated in different studies with acceptable outcomes.⁷¹⁻⁷⁴ Although not appropriate for refractory peritonitis, simultaneous removal and reinsertion may be considered for relapsing peritonitis in which the PD effluent cell count and culture have normalized after an appropriate duration of treatment. Crabtree and Siddiqi⁷⁵ analyzed the clinical outcomes of 55 cases that had laparoscopic simultaneous catheter replacement at 1 center. Of those, 28 had relapsing peritonitis and 12 had refractory tunnel infections without peritonitis. The causative organisms in the peritonitis cases were coagulase-negative staphylococci in 26 cases, *S aureus* in 1 patient, and *Streptococcus viridans* in 1 patient. For the tunnel infections, the majority were secondary to *Pseudomonas aeruginosa*. All patients were kept on antibiotic therapy until the procedure was performed and continued for 2 to 4 weeks after the procedure. In all cases of peritonitis and tunnel infections, PD was resumed at the day of surgery using a day-dry, supine, low-volume APD protocol. At 8 weeks follow-up, all patients were able to continue PD with no subsequent relapse of peritonitis, pericatheter or incisional leaks, or exit-site or wound infections.⁷⁵

In a recent French experience by Viron et al,⁷⁶ 11 patients who had simultaneous removal and insertion of the PD catheter were analyzed. The causative organisms in those patients were Gram-positive in 5 patients, Gram-negative in 4 patients (1 of which was *Pseudomonas*), and yeast in 2 patients who refused to convert to HD. Eight (73%) patients were able to continue PD without transfer to HD and of those, 7 were still on PD at 1 year with no relapse of peritonitis. Of the 2 fungal peritonitis cases, one was able to continue PD for 15.9 months, while the other could not resume dialysis.⁷⁶

The effectiveness of the 1-step strategy is well demonstrated in select cases of Gram-positive relapsing peritonitis and refractory exit-site and tunnel infections, whereas it remains unclear for enteric, *Pseudomonas*, and fungal-related peritonitis.⁷⁷ As a result, in our center, simultaneous PD catheter removal and reinsertion for relapsing peritonitis is considered for only select organisms and we extend antibiotic therapy over the course of the procedure and in the week following the new PD catheter placement.

10. NOT ALL PERITONITIS IS PD PERITONITIS

Peritonitis that results from non-PD-related complications (eg, ruptured appendix, ischemic bowel, and cholecystitis) is well reported but still uncommon. Differentiating this from peritonitis that is PD related can be very challenging because both can have similar presentations. The ISPD recommends extending empirical antibiotic coverage to include metronidazole plus vancomycin in combination with ceftazidime or an aminoglycoside when a surgical cause of peritonitis is suspected. Another alternative is monotherapy with a carbapenem or piperacillin/tazobactam.¹¹ Although some PD centers and emergency departments perform computed tomography routinely in patients presenting with features of PD-related peritonitis, the role of imaging in establishing the diagnosis of PD peritonitis is limited. However, computed tomography in some select cases of peritonitis can be of value in detecting loculated fluid collections or abscess, thickening of the small-bowel wall or adhesions, and exclusion of other causes of intra-abdominal sepsis.^{78,79} We suggest that computed tomography be performed in the following cases: patients with polymicrobial enteric organisms, especially those who fail to respond to appropriate treatment clinically or biochemically; hypotensive or hemodynamically unstable patients; patients with accompanying bacteremia; or patients with other gastrointestinal symptoms (such as severe nausea and vomiting) or more localized abdominal pain that may suggest another pathology or abnormal blood test results (elevated lipase, bilirubin, or transaminase enzyme levels). Of note, mild elevation in serum lactate level in patients with peritonitis may not necessarily indicate tissue hypoperfusion or bowel ischemia because it can be the result of delayed metabolism of the lactate buffer used in the PD solutions.⁸⁰

If imaging of the abdomen in these cases is performed, air under the diaphragm may be a finding. However, the clinical significance of this sign can be variable. The cause of pneumoperitoneum in PD patients is mostly related to the PD catheter because it can provide an access for free air to enter the peritoneum cavity. The incidence of this finding in PD patients has decreased from as high as 34% in older studies to as low as 4% in a more recent study.⁸¹⁻⁸⁴ This decrease in incidence is likely related to the advances in PD connectology that limit the introduction of intraperitoneal air during an exchange and

enhanced patient education regarding proper technique. Taken together, this radiologic finding is common in PD patients in the absence of intra-abdominal pathology; however, it should not always be considered as an incidental benign finding. The right clinical context (ie, polymicrobial enteric peritonitis), a detailed history and physical examination, and adjunct additional supportive imaging findings to suggest a surgical cause should be considered to differentiate benign from more concerning causes.

CONCLUSIONS

Peritonitis carries substantial morbidity and mortality. The evidence on how best to treat peritonitis is lacking. However, using the best available evidence can improve PD practice and patients' outcomes. When evidence is lacking, clinical judgment should ensue with the ultimate goal of reducing the morbidity associated with PD peritonitis while maximizing treatment success.

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