Updates on Infectious and Other Complications in Peritoneal Dialysis: Core Curriculum 2023

Sana F. Khan

The last few years have seen several developments in the field of peritoneal dialysis (PD), including successful use of acute PD, increasing emphasis on home dialysis utilization, and improved understanding of models of peritoneal solute transfer. This installment of AJKD's Core Curriculum in Nephrology emphasizes the latest data available for prevention and management of infectious and noninfectious complications of PD. Through case vignettes, appropriate strategies for diagnosis and care of patients with PD peritonitis are reviewed as well as noninfectious complications evident in clinical practice including complications from increased intra-abdominal pressure, namely pericatheter and abdominal leaks, hernia formation, and complications from pleuroperitoneal communication (hydrothorax). Although rates of incisional hernias and pericatheter leaks have decreased with improved peritoneal dialysis catheter insertion techniques, these mechanical complications continue to be common occurrences and are reviewed via pertinent clinical vignettes which aim to address and discuss common implications of these scenarios. Finally, this Core Curriculum article covers a practical overview of peritoneal dialysis catheter dysfunction.

Complete author and article information provided at end of article.

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The Core Curriculum aims to give trainees in nephrology a strong knowledge base in core topics in the specialty by providing an overview of the topic and citing key references, including the foundational literature that led to current clinical approaches.

Introduction

From 2009 to 2019, the percentage of incident dialysis patients performing peritoneal dialysis (PD) increased from 6.6% to 12.3% in the United States. Among patients who initiated PD, the cumulative incidence of conversion to in-center hemodialysis is reported to be approximately 25% at 2 years, most commonly due to peritonitis, inadequate dialysis, mechanical problems, and social determinants of health. There have been several improvements in care for PD-associated complications, and these may have contributed to a recent decreased rate of hospitalization for PD patients. This installment of *AJKD*'s Core Curriculum in Nephrology focuses on the latest data regarding care and prevention of infectious and noninfectious complications of PD.

Infectious Complications

PD-related infections include peritonitis, exit site infections, and tunnel infections. According to the 2022 US Renal Data Systems report, peritonitis episodes accounted for 5.9 hospital admissions per 100 patient-years, decreased from 15.1 admissions per 100 patient-years a decade ago. Several initiatives in recent years—Peritoneal Dialysis Outcomes Practice Patterns (PDOPPS), Optimizing Prevention of PD Associated Peritonitis in the US (OPPUS), and the International Society of Peritoneal Dialysis (ISPD)—have updated data and guidelines on infection-related complications. Additionally, the ongoing Standardizing Outcomes in Nephrology (SONG-PD) initiative has identified infectious complications as a primary concern of all stakeholders involved in PD care. PD-associated peritonitis is the most common infectious complication of PD and is associated with several negative clinical consequences, including hospitalizations, increased health care utilization and costs, associated mortality, and alterations to the peritoneal membrane. It is the leading cause of transfer to hemodialysis.

Case 1: *A 41-year-old woman with a history of type 2 diabetes mellitus, hypertension, end-stage kidney disease (ESKD) on continuous ambulatory peritoneal dialysis (CAPD) presents for her monthly clinic visit. She reports no problems with her dialysis regimen but also reports tenderness 2 cm inferior to her exit site. She is adherent to her exit site care and prophylactic antibiotic ointment use. On physical examination, there is mild erythema around the exit site and some purulent drainage on milking the tissue near the catheter exit site.*

Question 1: What is the next best step in management?

(a) Empirical oral antibiotic coverage
(b) Exit site drainage culture followed by empirical oral antibiotics
(c) Ultrasound of dialysis catheter tunnel to exclude tunnel infection
(d) Removal and reinsertion of dialysis catheter

For the answer to this question, see the following text.

Catheter-related infections are a major predisposing factor in PD-related peritonitis. They include exit site infections as well as tunnel infections, and the primary objective of preventing and treating catheter-related infections is to prevent peritonitis. Exit site infections are defined as the presence of purulent discharge at the catheter-epidermal junction. Erythema at the exit site can be concomitant with exit site infection, but can also be a result of skin irritation (antibiotic ointment, cleansing agents), exit site trauma, and granulation tissue after new catheter placement. Exit site erythema alone can represent an infection.

For this patient in question 1, the best choice is (b), a swab for culture and empirical antibiotics such as a 2-week course of trimethoprim-sulfamethoxazole. Empirical oral antibiotic coverage without exit site culture (a) is not appropriate because microbial sensitivities and cultures guide future therapy. Removal of the dialysis catheter (d) is appropriate in cases of refractory exit site infections whereas an ultrasound of the PD catheter is indicated in cases of refractory exit site infection, pain or erythema along catheter tunnel, and concurrent exit site infection and peritonitis.

Initial empirical treatment of exit site infections should include therapy against *Staphylococcus aureus*, which is the most common exit site pathogen in programs that do not use anti-staphylococcal exit site prophylaxis. Other organisms that are also known to cause exit site and tunnel infections include coagulase-negative staphylococcal species, nontuberculous *Mycobacteria*, streptococci, and Gram-negative bacilli. Antimicrobial therapy should be continued for 2 weeks (or until the exit site appearance has normalized), unless the causative agent is *Pseudomonas*, in which case 3-week coverage with 2 antimicrobial agents is recommended.

Case 1, continued: *This patient's exit site swab results showed methicillin-resistant* Staphylococcus aureus *(MRSA). She completed her 2-week prescribed course of trimethoprim-sulfamethoxazole. The exit site drainage diminished, though it was still persistent. A focused abdominal ultrasound revealed no obvious abscess or fluid collection along the catheter tunnel. The patient received an additional week of antimicrobial coverage with oral trimethoprim-sulfamethoxazole, with no significant improvement in exit site drainage.*

Question 2: What is the most appropriate next step in management?

(a) Removal of dialysis catheter and transition to hemodialysis
(b) Simultaneous removal and reinsertion of catheter at a different location
(c) Transition to a different oral antimicrobial coverage
(d) Start intraperitoneal antibiotics

For the answer to this question, see the following text.

Possible indications for catheter removal in exit site and tunnel infections are summarized in Box 1; these include infections that occur simultaneously with peritonitis episodes or lead to subsequent peritonitis episodes, in addition to refractory catheter infections (failure to respond after 3 weeks of effective antibiotics).

Box 1. Indications for Catheter Removal in Catheter-Related Infections

- Catheter infections occurring simultaneously with peritonitis
- Catheter infections leading to peritonitis
- Refractory catheter infections (failure to resolve after 3 weeks of treatment)

There are currently no randomized controlled trials regarding optimal catheter interventions in the cases of refractory or chronic catheter infections. Studies have reported favorable results with simultaneous removal and reinsertion of new catheter at a different exit site under antimicrobial coverage, so the answer is (b). Transition to hemodialysis (a) is currently not indicated, and intraperitoneal antibiotics (d) are not appropriate with exit site infections. A different antimicrobial regimen (c) is not appropriate, given the adequate coverage against MRSA by the prescribed trimethoprim-sulfamethoxazole.

A few observational studies have reported cuff shaving with exteriorization of the external cuff, with resolution of the pocket of infection. Although this strategy may be successful, this approach has a significant risk of peritonitis. Another approach for catheter salvage that has been reported as an alternative to catheter removal is a catheter diversion procedure with exit site renewal in a new location, though there are no randomized trials to show the superiority of this approach.

Case 1, continued: *This patient underwent successful catheter diversion, with effective eradication of the catheter infection. She subsequently returned to the clinic to discuss additional strategies to prevent catheter infections besides her usual exit site care and ointment application.*

To date, most studies have examined rates of catheter infection as a secondary outcome, with peritonitis as the primary outcome. Most catheter infection prevention strategies are based on best practice guidelines. Although the use of perioperative antibiotics at the time of catheter insertion has been shown to reduce the rate of early peritonitis, some studies have shown reduced rates of early catheter infections as a secondary outcome. There is currently no difference in catheter infections per technique of catheter placement or nephrologists versus surgeons. The location of the catheter exit site should be away from the beltline and skin folds, and it should be easily visible to the patient. Additionally, it is strongly recommended to avoid any sutures at the exit site. Specific to catheter-related infection, no particular catheter design (swan

neck vs straight, single cuff vs double cuff) has been shown to be superior to another. Small studies have reported the use of extended swan neck catheters in patients who need upper abdominal exit sites (obesity, stomas), and it has been shown to have lower rates of catheter infections compared with conventional abdominal catheters.

Several topical cleansing agents have been tested, including povidone-iodine, chlorhexidine solution, and sodium hypochlorite; preference on use is center-specific. Daily topical antibiotic application at the exit site has been shown to reduce catheter infection rates. Commonly studied antimicrobials include topical mupirocin, which has been shown to reduce rates of *S aureus* infections, and gentamicin which has been shown to be effective against *S aureus*, Gram-negative bacilli, and *Pseudomonas*. Recent data suggest that exit site mupirocin is most commonly used in Australia, New Zealand, Canada, and the United Kingdom, whereas exit site aminoglycosides is most common in the United States.

Case 2: *A 69-year-old man with a history of ESKD on CAPD presents to the emergency department (ED) with a 2-day history of abdominal pain and cloudy abdominal fluid. These symptoms are associated with ongoing nausea and inability to tolerate oral intake. He reports that his symptoms are similar to a prior episode of peritonitis that occurred 1 year ago. He also reports a history of constipation for 1 week before his presentation. In the ED, he appears uncomfortable, with abdominal tenderness on palpation. The PD catheter exit site has no erythema or drainage. Drained peritoneal effluent appears cloudy. Effluent samples are sent to the laboratory for cell counts and cultures.*

Question 3: What is the next best step in management?

(a) Intraperitoneal vancomycin and gentamicin
(b) Rapid peritoneal lavage
(c) Oral ciprofloxacin
(d) Aggressive bowel regimen

For the answer to this question, see the following text.

Given his ongoing nausea and inability to tolerate oral intake, this patient was admitted to the hospital. Other indications for his admission include hemodynamic instability and concerns for his visceral intra-abdominal pathology. The definition of peritonitis is summarized in Box 2. Peritonitis is diagnosed when at least 2 of the following are present: clinical presentation of peritonitis (abdominal pain and/or cloudy effluent), dialysis effluent white cell count > 100/μL with > 50% polymorphonuclear cells, or a positive effluent culture. A recent analysis of PDOPSS data showed the most common causative organisms are Gram-positive organisms, followed by Gram-negative organisms, culture negative peritonitis, polymicrobial infections, and yeast. Intraperitoneal empirical antibiotics

Box 2. Definition of Peritonitis

Presence of at least 2 of the following:
- Clinical features consistent with peritonitis; abdominal pain / cloudy effluent
- Dialysis effluent white blood cell count > 100/μL with >50% polymorphonuclear cells
- Positive dialysis effluent culture

regimens covering both Gram-positive (first-generation cephalosporin, vancomycin) and Gram-negative (third-generation cephalosporin, aminoglycosides) organisms are recommended until the culture results are available. Rapid peritoneal lavage is not indicated if timely administration of intraperitoneal antibiotics is possible (b). Oral antimicrobials (c) and bowel regimen (d) are not indicated for suspected peritonitis.

This patient has the clinical scenario of suspected peritonitis and thus prompt antimicrobial therapy should be initiated, so the correct answer is (a). Center-specific data concerning methicillin-resistant organisms and *Pseudomonas* determines use of vancomycin and aminoglycosides, respectively. Observational data suggest a similar peritonitis cure rate with vancomycin and cefazolin in cases of Gram-positive and culture-negative infections. Additionally, the same analysis reported a higher likelihood of cure with aminoglycosides than with ceftazidime.

Recommended initial empirical antibiotics and their dosages are summarized in Table 1. Besides choice of empirical therapy, prompt administration of antibiotics has been shown to be associated with better outcomes in peritonitis treatment. Studies have shown an increased risk of PD failure, catheter removal, and death with delays in antibiotic administration. Subsequent culture results and sensitivities are used to tailor the antibiotics and determine duration of treatment. Although intraperitoneal antibiotic administration is preferred, systemic antimicrobial administration may be necessary in cases of acute decompensation or inability to obtain and administer via the intraperitoneal route. Organism-specific treatment durations are summarized in Table 2.

Case 2, continued: *The PD effluent cell counts were 6,900 white blood cells (WBCs) with 93% polymorphonuclear cells. After the initial 6-hour dwell with intraperitoneal antibiotics, the patient continued on his ambulatory PD regimen. Given the history of constipation before his presentation, osmotic laxatives were administered. His abdominal pain gradually improved, and the patient was able to tolerate oral intake. Gram-negative coverage was continued for 48 hours before repeating the effluent analyses. On day 3, his initial culture results showed coagulase-negative* Staphylococcus *and* Enterococcus. *Repeat cell counts revealed 700 WBCs with 40% polymorphonuclear cells. What would be the next step in management?*

Table 1. Empiric Treatment of Peritonitis

Organisms Covered	Initial Agents	Example Doses for Intermittent (Once Daily) Dosing
Gram positive	• First-generation cephalosporins • Vancomycin	• Cefazolin, 15-20 mg/kg • 15-30 mg/kg (dosed 5-7 days, systemic level > 15 mg/L
Gram negative	• Third-generation cephalosporins • Aminoglycosides	• Cefepime, 1000 mg; or ceftazidime, 1,000-1,500 mg • Gentamicin 0.6 mg/kg

This patient has polymicrobial peritonitis. Although repeat cell counts suggest resolution of the infection, polymicrobial infections warrant investigations for an intra-abdominal pathology. This patient underwent an abdominal computed tomography (CT) scan, which did not suggest diverticulitis or visceral perforation. Antibiotics were tailored via intraperitoneal cefazolin and vancomycin, and the patient remained well after completion of a 3-week course of antibiotics.

Given the increased morbidity, cost, and concerns for PD failure resulting from infectious complications, several interventions for infection prevention have been recommended in recent years. Before initiation of PD, important aspects of infection prevention include the presurgical evaluation, mainly selection of an appropriate PD catheter as well as exit site location, and patient education on perioperative care and healing time. Several centers have adopted preinitiation home visits assessing the suitability of the home environment, specifically regarding pets, hygiene, and the location where PD will be performed.

Use of antibiotics at the time of catheter insertion has been noted to be reduce the risk of peritonitis. The antibiotics studied include vancomycin and cefazolin, and local resistance patterns should determine the type of antibiotic used. Despite this evidence-based recommendation, data from several centers in the United States have reported use of precatheter antibiotics in only 63% of centers. In an observational study looking at outcomes in single-cuff versus double-cuff catheters, lower rates of Gram-positive infections were noted in the double-cuff group, most likely due to the additional barrier to skin organisms provided by the subcutaneous cuff.

Table 2. Organism-specific Treatment Duration for Peritonitis

Organism	Recommended Treatment Duration for Peritonitis
Staphylococcus aureus	21 days
Streptococci/Coagulase-negative *Staphylococcus*	14 days
Enterococcus	21 days
Gram-negative organisms	21 days
Polymicrobial organism	21 days
Pseudomonas	Double antimicrobial coverage for 21 days
Fungal	Catheter removal, 14 days of antimicrobial coverage
Culture negative	14 days of Gram-positive coverage

Individualized training over multiple days has been recommended as optimal training. Also, training styles should be adapted to patients and their care partners. A study surveying clinic training practices revealed marked variations in days, locations, and training modalities and did not identify any associated factors specifically predicting peritonitis risk. Best practices are currently not known and need further investigation.

Post-PD initiation, ongoing adaptations in PD connectology specifically "flush before fill," and the Y set for PD exchanges have been instrumental in peritonitis prevention. Additionally, several instances of prophylactic antibiotics have been recommended in the latest ISPD guidelines. Empirical antimicrobial prophylaxis before colonic or gynecologic procedures has been recommended, and the procedures should be performed on a dry abdomen. Instances of "wet" contamination (such as leak from dialysate bags, leaks in tubing, breach of aseptic technique, and exchange performed after touch contamination) have been associated with peritonitis events. In this event, recommendations include utilization of prophylactic antibiotics as well as transfer set change or repair. Instances of "dry" contamination only necessitate extension tubing change.

Other risk factors for peritonitis include hypokalemia and gastrointestinal problems, including constipation and gastrointestinal bleeding. Although the evidence is not robust, mitigation of these concerns is routinely recommended in PD patients. In addition, retraining is recommended, ideally with a home visit, after an episode of peritonitis, prolonged hospitalization, or a change in functional status. Assessment of changes in the home environment and direct visualization of PD technique in the home setting is an essential component of the retraining visit.

Most fungal peritonitis episodes are preceded by systemic antibiotic administration. Secondary prevention of fungal peritonitis has been studied in several observational and randomized trials, and studies have examined oral nystatin or fluconazole as prophylactic agents. Given the high rates of PD failure and catheter removal with fungal peritonitis, prophylaxis is recommended to continue for 1 week after completion of systemic antibiotics.

Ongoing infection control efforts include standardizing and tracking infection outcomes, reducing disparities in peritonitis access, and measures to improve PD access placement and connectology. Outcome specific definitions of peritonitis have also been revised in the latest ISPD guidelines and have been referenced in the additional

reading. Table 3 summarizes infection prevention efforts. There is currently an increased emphasis on decreasing the rate of culture-negative peritonitis, with specific attention paid to fluid specimen collection and handling procedures. Dialysis units should perform continuous quality improvement measures to track and improve infection rates.

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Table 3. Infection Prevention Interventions

Time Line	Intervention
Pre-PD	• Surgical evaluation; mapping location of exit site • Patient education on catheter care and healing • Selection of appropriate catheter type • Home visit assessment; identifying risk factors for infections (pets, hygiene, window/vent locations)
Transition to PD	• Perioperative antibiotics • Selection of double-cuff catheter • Nurse trainers with maintaining ongoing competencies
Post-PD initiation	• Flush before fill connectology • Exit site gentamicin/mupirocin • Prophylactic antibiotic use—wet contamination, colonoscopy, catheter break • Antifungal prophylaxis with systemic antibiotic use • Prevention of hypokalemia • Prevention of constipation • Avoidance of histamine-2 receptor antagonists • Retraining and home visits with direct technique visualization (hospitalizations, infections, change in functional status)

Abbreviation: PD, peritoneal dialysis.

Noninfectious Complications

Clinically important noninfectious complications of PD include PD catheter malfunction, complications related to increased intra-abdominal pressure (leaks, hernias, and hydrothorax), abnormal appearances of PD effluent, cardiometabolic complications, and concerns associated with membrane dysfunction. In recent years, the ISPD has published updated guidelines on the assessment of peritoneal membrane function as well as encapsulating

peritoneal sclerosis. The SONG-PD initiative highlighted the importance of membrane function for patients, caregivers, and health care teams.

Case 3: *A 56-year-old man with ESKD on automated PD for the last 5 years presents for his monthly clinic visit. He has a history of multiple episodes of peritonitis and has had challenges with ultrafiltration, necessitating several prescription adjustments and utilization of 4.25% dextrose solution as well as a long icodextrin day dwell. He is currently experiencing worsening shortness of breath and lower extremity edema. A modified peritoneal equilibration test (PET) revealed appropriate ultrafiltration. After counseling on fluid and sodium restriction, he was able to continue on PD with minor prescription adjustments. One year later, he was admitted to the hospital with abdominal fullness, weight loss, persistent nausea, and vomiting. Peritoneal fluid analysis did not reveal peritonitis. An abdominal CT scan revealed dilated loops of small bowel, tethered in an envelope of thickened peritoneum. The patient is concerned about the potential diagnosis and treatment plan moving forward.*

Given his current symptoms as well as the structural CT scan appearance, this patient has most likely developed encapsulating peritoneal sclerosis (EPS). Box 3 lists the pertinent radiographic findings of EPS. It is an extremely rare complication of long-term (>5 years) PD. Given its rarity and the heterogeneity of etiologies, estimates of the prevalence of EPS vary from 0.4%-8.9%. The reported mortality is around 50% within a year of diagnosis. EPS is diagnosed in a variable number of patients after PD cessation, including after kidney transplant, and there is also marked variation in the number of patients followed after transition to hemodialysis or transplant. There has been an observed decline in the incidence of EPS; this is thought to be multifactorial, including decreased use of hypertonic glucose solutions, increased rates of transplant, increased use of biocompatible solutions, and the competing risks of death.

The risk factors for EPS include time on dialysis (most common), patients who develop fast peritoneal solute transfer rates, and refractory peritonitis. A 2-hit hypothesis has been proposed for EPS development, starting with exposure to the PD catheter, hyperosmotic and acidic glucose-containing solutions resulting in mesothelial cell damage, and peritoneal sclerosis. The nature of the second hit is unclear but is proposed to include peritonitis episodes or genetic predisposition. Although there is no proven strategy to reduce the risk of EPS, there is some evidence to support minimizing exposure to high-glucose dialysate, prevention of peritonitis, as well as utilization of more biocompatible PD solutions. There is currently no evidence to support screening abdominal CT scans to predict the development of EPS.

There is currently no gold standard for an EPS diagnosis; instead, diagnosis is based on a constellation of clinical findings along with radiographic confirmation. Anorexia and weight loss are common early symptoms. With time, thickening of encapsulation can result in bowel obstruction and ileus. Often symptoms improve with bowel rest but can progress to bloody ascites, severe abdominal pain, and malnutrition.

Patients are typically transitioned to hemodialysis, though some cases have been reported to worsen after PD cessation. Some centers have performed repeated peritoneal lavage (proposed to remove mediators of fibrotic processes), though it is unclear if this approach has any benefits. Nutritional support, parenteral if necessary, is imperative in the management of EPS. Several pharmacologic agents have been reported to be beneficial in relatively small studies, including corticosteroids, tamoxifen, and sirolimus. For patients with persistent bowel obstruction, several centers have published data on successful surgical interventions with decortication of fibrous membrane and lysis of adhesions. Currently, there is insufficient evidence regarding optimal time on PD to prevent EPS risk. Each patient warrants an individualized approach, specifically with regards to age, prognosis, quality of life, quality of life on PD, and the potential risks associated with transition to hemodialysis.

Biomarkers in dialysis effluents is an active area of research in predicting EPS. Given the long-term follow up needed after PD cessation and kidney transplant, such approaches may be difficult to assess in practical EPS prediction.

Box 3. Computed Tomography (CT Scan) Findings of Encapsulating Peritoneal Sclerosis

- Peritoneal calcification
- Bowel-wall thickening
- Bowel tethering and dilation
- Signs of small intestinal obstruction
- Ascites/localized fluid collection

Additional Readings

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Complications Related to Increased Intra-Abdominal Pressure

The presence of dialysate in the peritoneal cavity leads to increased intra-abdominal pressure, which increases in proportion to the instilled dialysate volume. A 2-liter intraperitoneal volume in the supine position has been shown to result in values from 13.2 to 18.8 cm H_2O. Every 500 mL increase in volume is associated with a linear elevation in pressure. The intra-abdominal pressure is lowest in the supine position and increases incrementally in the sitting and standing positions. Certain physical activities (coughing, straining) can result in marked transient intra-abdominal hypertension. Elevated intra-abdominal pressures and anatomic defects of the peritoneal cavity boundary can lead to hernias, genital and abdominal wall leaks, and hydrothorax (pleuroperitoneal communications). Patients with polycystic kidney disease are thought to be predisposed to these complications, either as a result of higher intra-abdominal pressures caused by the large kidneys or as a consequence of altered connective tissue.

Case 4: *A 52-year-old man with a history of stage 5 chronic kidney disease underwent PD catheter placement, and training sessions are started 2 weeks after catheter placement. The patient starts with a regimen of 2-liter fill volumes for 4 exchanges each day. The day after initiating exchanges at home, he notices moisture on his catheter dressing. On examination in clinic, there is noticeable moisture around catheter exit site. Of note, the patient had residual kidney function of 8 mL/min/1.73 m² at the time of catheter insertion.*

Question 4: What is the next best step in this case?

(a) Transition to intermittent hemodialysis
(b) Hold peritoneal dialysis exchanges for 2 weeks
(c) Placement of suture at catheter exit site
(d) Revision of peritoneal dialysis catheter

For the answer to this question, see the following text.

This patient presents with an early leak (<30 days after catheter insertion). Loss of peritoneal membrane integrity (opening or a tear) leads to dialysate leaks in PD patients. Generally, early leaks are thought to be related to catheter insertion techniques, timing of initiation of PD, and strength of abdominal wall tissues; they manifest as visible moisture or leakage at catheter exit site or incision wound. Dialysate leakage can be identified by a positive glucose dipstick. Additionally, imaging (CT scan or ultrasound) may demonstrate pericatheter fluid tracking. Historically, midline catheter insertion techniques predispose patients to early leaks. With the current practice of paramedian catheter insertion, the risks include obesity and conditions that predispose to poor wound healing (mTOR inhibitors, ongoing glucocorticoid use, chemotherapy).

The current ISPD guidelines recommend a 2-week break-in period before elective PD start. For acute and urgent start regimens necessitating catheter use within 2 weeks of placement, a low-volume recumbent intermittent regimen is recommended, with a dry peritoneal cavity during ambulatory periods. Specific catheter insertion-related interventions to mitigate early complications include utilization of fibrin glue and additional purse-string sutures at the level of deep cuff as well as near the peritoneal membrane. Stopping PD temporarily or employing regimens with minimal impact on intra-abdominal pressure is usually effective in treating early leaks.

In this patient's case, the answer is (b), either temporary cessation of PD or a regimen of 1-liter exchange volume while supine would be appropriate management. Transition to intermittent dialysis (a) is not needed because this patient still has some residual kidney function. Exit site sutures (c) impair exit site healing and increase risk of infections, and are also not appropriate. Catheter removal and reinsertion (d) is appropriate management in refractory cases of exit site leaks. Exit site leaks increase the risk of PD-related infections, and prophylactic antibiotics may be necessary.

Late leaks (>30 days after catheter insertion) are often related to mechanical tears in the peritoneum, resulting in dialysate extravasation into the abdominal wall, external genitalia, or retroperitoneal cavity. Depending on the location of the leak, patients may report localized fullness and edema around scrotal sac/labia majora, boggy abdominal wall skin, and decreased ultrafiltration volumes with normal dialysis catheter flows. Examination may reveal asymmetric edema, boggy skin, and skin indentations made by tight clothing. Pathways for late leaks include a patent processus vaginalis (more common in men than women) or soft tissue defects within hernias or peritoneofascial defects.

CT scans with intraperitoneal contrast and images taken 2-3 hours after dialysate instillation are utilized to visualize these leaks. Additionally, tracking the pathways to the edema/leak can help guide further interventions. Abdominal scintigraphy with technetium-99 has also been used to diagnose leaks and concomitant hernias. Management of genital edema includes bed rest, scrotal elevation, and use of frequent low-volume automated cycler PD. Abdominal wall leaks necessitate cessation of PD for 1-2 weeks to allow for healing of the leak. Those patients are unresponsive to low volume regimens, and temporary PD cessation usually requires surgical correction with temporary transition to hemodialysis.

Case 5: *A 72-year-old man with a prior right radical nephrectomy and a recent progression to ESKD underwent PD catheter placement and subsequent training. The first night of dialysis at home, the patient noted acute shortness of breath and "fullness" of his right chest/back. Physical examination revealed dullness to percussion and decreased breath sounds on the right side. A chest X-ray revealed a large right sided pleural effusion. A focal lucency was visible, concerning for a bowel loop within a small diaphragmatic hernia. CT scans confirmed the presence of a diaphragmatic defect with small hernia. Diagnostic thoracentesis was performed, which revealed a transudative effusion with glucose level 350 mg/dL (the concurrent serum glucose was 157 mg/dL). Peritoneal dialysis was held for 2 weeks, with repeat imaging demonstrating persistent large pleural effusion.*

Question 5: What is the next best step in this patient's management?

(a) Video-assisted thoracoscopic repair of diaphragmatic defect
(b) Thoracoscopic pleurodesis
(c) Thoracentesis following methylene blue instillation in pleural fluid
(d) Contrast CT peritoneography

For the answer to this question, see the following text.

Hydrothorax in PD patients is an uncommon (incidence 1.6%-10% of patients) but well recognized complication. An increased intra-abdominal pressure results in the leak of dialysate across the diaphragm into the pleural space. It is most commonly noted to be right-sided, with occasional reports of left-sided or bilateral occurrence. The mechanisms for hydrothorax development include congenital or acquired diaphragmatic defects, increased pleuro-peritoneal pressure gradients, as well as lymphatic drainage disorders. In this patient's case, the diaphragmatic defect was attributed to an iatrogenic injury from a previous procedure, such that the hydrothorax developed with increased abdominal pressure secondary to peritoneal dialysate. In certain patients, hydrothorax develops rapidly after PD initiation, indicating a pre-existing pleuro-peritoneal communication. It also exists patients on long-term PD, suggesting an acquired manner, with attenuated tissue being repeatedly exposed to raised intra-abdominal pressure, and development of pleuro-peritoneal communication.

The severity of symptoms depends on the size of the pleural effusion, and the patient may experience reduced ultrafiltration volumes. The symptoms may be similar to congestive heart failure but will not be relieved by using hypertonic dialysate (increased intra-abdominal pressure with increased ultrafiltration).

In this patient's case, imaging was concerning for an obvious diaphragmatic defect. Origin of pleuro-peritoneal communication can be detected via contrast CT peritoneography (Option D) and peritoneal scintigraphy using Technetium-99m tagged macro-aggregated albumin or Tc-99m sulfur colloid. Thoracentesis is consistent with a transudative effusion with a high glucose concentration (50 mg/dL greater than simultaneous blood glucose), however glucose measurement may be equivocal if prolonged effusion results in significant glucose absorption. Intraperitoneal methylene blue instillation followed by thoracentesis (Option C) has been utilized in certain instances, however there is a risk of chemical peritonitis.

Temporary (2-4 weeks) PD cessation results in resolution of pleural effusion, whereas a refractory hydrothorax suggests a unidirectional communication. There have been occasional reports of successful management utilizing low-volume cycler PD regimens. Successful thoracoscopic pleurodesis (oxytetracycline, talc, autologous blood) has been reported in certain cases (b); however, this invasive procedure is painful and with an increased risk of infection. This patient with a visible diaphragmatic defect was referred for surgical repair of the diaphragmatic hernia, so

the answer is (a). The patient was able to successfully transition back to PD after 4 weeks of postoperative intermittent hemodialysis.

Case 6: *A 62-year-old man with a 6-month history of ESKD on continuous cyclic peritoneal dialysis presents with a few weeks' history of bilateral groin swelling on instilling dialysate. Additionally, he reports an umbilical bulge on coughing. The patient denies any abdominal pain or overlying skin discoloration. Physical examination is consistent with a soft bilaterally reducible inguinal hernia and soft reducible umbilical hernia with a 3-cm palpable hernia opening.*

Question 6: What is the next best step in this patient's management?

(a) Transition to intermittent hemodialysis
(b) Surgical referral for conventional hernia repair
(c) Surgical referral for hernia repair with mesh placement
(d) No additional management

For the answer to this question, see the following text.

Various hernias have been described in PD patients, the common ones are incisional or through the catheter placement site, inguinal and umbilical hernias. Patients with hernias tend to be older, female, multiparous, obese, or with prior hernia repairs. One potential area of weakness is the abdominal incision for implantation of dialysis catheter, especially when the incision is a midline incision. Additionally, another area of potential weakness is a patent processus vaginalis (usually obliterated in most individuals). The increased abdominal pressure during PD may result in an indirect inguinal hernia due to bowel and bladder herniation in the processus vaginalis.

Most hernias present as a painless swelling. The most worrisome complications are incarceration and bowel strangulation, which occur more commonly with smaller hernias. Surgical repair is warranted, and pre-existing hernias can be repaired at the time of catheter insertion. Hernia repair with mesh (tension-free hernia repair) has been noted to result in a lower risk of recurrence and allows for a quicker recovery period and return to PD, so the answer is (c). Transition to intermittent hemodialysis is usually not necessary so long as the patient can tolerate up to 48 hours without dialysis and can restart supine low-volume (1-1.5 liter) dialysate exchanges, with gradual increase to the full presurgery prescription in 4 weeks.

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Peritoneal Dialysis Catheter Malfunction

PD catheter malfunction is a major cause of PD technique failure. Catheter malfunction can be outflow only or both inflow and outflow. Main causes of outflow obstruction include constipation, catheter tip migration, or omental or bowel wrap. Stool retention and catheter tip migration can be detected via plain film abdominal X-ray. Redundant omentum is the most likely cause of catheter encasement, with an outflow obstruction resulting from omentum obstructing catheter ports due to negative pressure outflow. Inflow and outflow obstruction both can be due to intraluminal (fibrin, clot) or extraluminal (catheter kink, fibrin sheath) processes.

Diagnostic and treatment measures for catheter malfunction are detailed in Figures 1 and 2. For outflow obstructions, initial management includes efforts to promote bowel movements and increase physical activity to help reposition the catheter. Irrigation with 50 mL of saline may be effective in dislodging a partial omental obstruction. For both inflow and outflow obstructions, catheter flush may be effective in

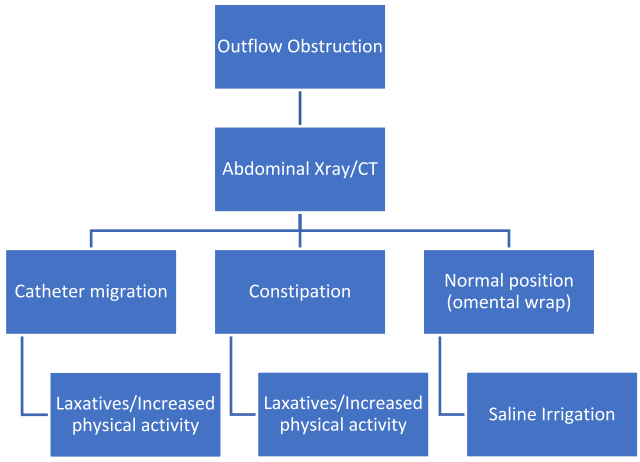

Figure 1. Diagnostic and treatment algorithm for catheter outflow obstruction. Abbreviation: CT, computed tomography.

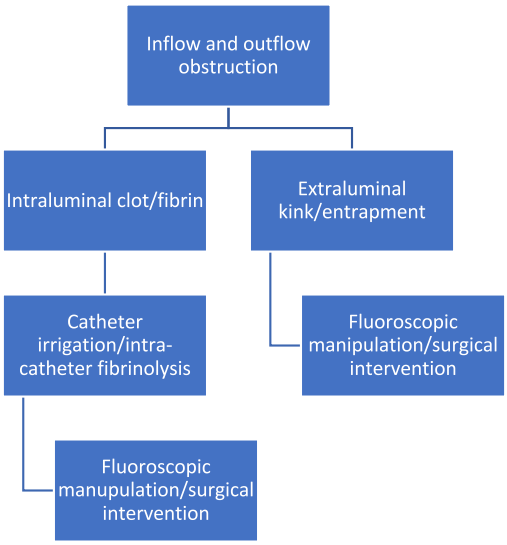

Figure 2. Diagnostic and treatment algorithm for inflow and outflow obstruction.

dislodging intraluminal clots/fibrin. Intraluminal fibrinolytics (heparin at 1,000 U/mL, urokinase at 2,000 IU/mL, or tissue plasminogen activator at 1 mg/mL) added in saline (10 mL) can be considered if irrigation is ineffective. If conservative measures fail, fluoroscopic manipulation or surgical interventions are needed.

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Article Information

Author's Affiliation: University of Virginia Health, Charlottesville, Virginia.

Address for Correspondence: Sana F. Khan, MD, University of Virginia Health, Box 800133, Charlottesville, VA 22908. Email: sk4yp@virginia.edu or sk4yp@uvahealth.org

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