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GUIDELINES

Guidelines for laparoscopic peritoneal dialysis access surgery

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Keyword Laparoscopic

Preamble

The use of peritoneal dialysis (PD) as a primary mode of renal replacement therapy has been increasing around the world. The surgeon's role in caring for these patients is to provide access to the peritoneal cavity via a PD catheter and to diagnose and treat catheter complications. Since the early 1990s, laparoscopy has been applied by many adult and pediatric surgeons for insertion of PD catheters as well as for salvage of malfunctioning catheters. This document is an evidence-based guideline based on a review of current literature and the opinions of experts in the field. It provides specific recommendations to assist surgeons who take care of adult and pediatric PD patients.

Disclaimer

Guidelines for clinical practice are intended to indicate preferable approaches to medical problems as established by experts in the field. These recommendations will be based on existing data or a consensus of expert opinion when little or no data are available. Guidelines are applicable to all physicians who address the clinical problem(s) without regard to specialty training or interests, and are intended to indicate the preferable, but not necessarily the only acceptable approaches due to the complexity of the healthcare environment. Guidelines are intended to be flexible. Given the wide range of specifics in any health care problem, the surgeon must always choose the course best suited to the individual patient and the variables in existence at the moment of decision. Guidelines are developed under the auspices of the Society of American Gastrointestinal and Endoscopic Surgeons and its various committees, and approved by the Board of Governors. Each clinical practice guideline has been systematically

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researched, reviewed and revised by the guidelines committee, and reviewed by an appropriate multidisciplinary team. The recommendations are, therefore, considered valid at the time of its production based on the data available. Each guideline is scheduled for periodic review to allow incorporation of pertinent new developments in medical research knowledge, and practice.

Literature review

A systematic literature search was performed on MEDLINE in May 2010 and was updated January 2013. Articles were limited to English language. Additional articles found on the latest search were included in the totals and incorporated into the guideline final draft. The search strategy is detailed in Table 1. Our search strategy identified 66 articles on laparoscopic insertion of PD catheters. Of these 37 were on salvage and 14 on peritoneoscopic insertion. The abstracts were reviewed by two committee members (SPH, JSR) and divided into the following categories:

(a) Randomized studies, meta-analyses, and systematic reviews
(b) Prospective studies
(c) Retrospective studies
(d) Case reports
(e) Review articles
(f) Clinical practice guidelines

Randomized controlled trials, meta-analyses, and systematic reviews were selected for further review along with prospective and retrospective studies when a higher level of evidence was lacking. For inclusion, prospective and retrospective studies had to report outcomes on at least 30 laparoscopic PD catheter insertions. Studies with smaller samples were considered when additional evidence was lacking. The most recent reviews were also included. All case reports, old reviews, and smaller studies were excluded. Duplicate publications or patient populations were considered only once. Whenever the available evidence from Level I studies was considered to be adequate, lower evidence level studies were not considered.

Table 1 Search strategy for adults

1.	Exp laparoscopy/ (53525)
2.	Exp peritoneal dialysis/(19953)
3.	Exp catheters/(14085)
4.	Exp catheterization/(159303)
5.	3 or 4 (167516)
6.	2 and 5 (1642)
7.	1 and 6 (154)
8.	Limit 7 to (English language and humans) (141)
9.	8 and 2006:2011.(sa_year).(39)
10.	Peritoneal dialysis catheter:.mp. (560)
11.	1 and 10 (115)
12.	Limit 11 to (English language and humans) (106)
13.	Limit 12 to “all adult (19 plus years)” (66)

Table 2 Search strategy for pediatrics

1.	Peritoneal dialysis 14640
2.	Catheters, Indwelling 16007
3.	1 AND 2 788
4.	Limit 3 to English Language and humans 712
5.	Limit 4 to “all child (0–18 years)” 148
6.	Limit 5 to years = 1985–2013

The reviewers graded the level of evidence and searched the bibliography of each article for additional articles that may have been missed during the original search. Additional relevant articles were obtained and included in the review for grading. A separate search pertaining to pediatric patients was undertaken in 2013. The search strategy is outlined in Table 2. Due to lower case numbers, prospective and retrospective studies in pediatric patients had to report outcomes on at least 15 PD catheter insertions. Studies with smaller samples were considered when additional evidence was lacking. Forty five articles relevant to pediatric patients were reviewed by a committee member (DW). Overall, a total of 170 graded articles relevant to laparoscopic PD insertion were included in this review to formulate the recommendations in this guideline.

Levels of evidence

The quality of the evidence and the strength of the recommendation for each of the guidelines were assessed according to the GRADE system. There is a four-tiered system for quality of evidence (very low (⊕), low (⊕⊕), moderate (⊕⊕⊕), or high (⊕⊕⊕⊕)) and a 2-tiered system for strength of recommendation (weak or strong).

Introduction

The concept of PD has been a work in progress for over a century. The first report of “peritoneal irrigation” as a successful treatment of renal failure was in 1946 by Frank, Seligman, and Fine [1]. Grollman continued to advance the technique using a dog model at University of Texas Southwestern Medical School [2]. Maxwell and colleagues were the first to describe a technique similar to today’s form of PD exchanges in a “closed system” using commercial solutions, disposable tubing, and a nylon catheter [3]. By 1980, continuous ambulatory PD (CAPD) had become a proven mode of renal replacement therapy [4, 5] and was being offered in over 116 medical centers in the United States [4, 5]. Its use has steadily grown throughout the world so that the percent of renal failure patients on PD in 1998 were: 13 % USA, 37 % Canada, 42 % UK, 91 % Mexico, 81 % Hong Kong, and 6 % Japan [6]. Recent data show the utilization has fallen to seven percent in the United States [6, 7] and many believe this decline is due to a lack of available experts to place and care for the catheters [8]. In contrast to adults, 40 % of patients ages 0–19 initiate and are maintained on PD, with 96 % of infants and toddlers using this modality [7, 9]. Across the globe, PD catheters are placed by nephrologists, surgeons, and interventional radiologists based on availability and individual expertise. PD catheters may be placed at the bedside, in a fluoroscopic suite or an operating room. This guideline will discuss patient selection and insertion options while focusing on techniques of laparoscopic PD catheter insertion. It will also review evaluation and management of malfunctioning catheters, again focusing on laparoscopic surgical techniques.

Patient selection

Guideline recommendation

1. Contraindications for laparoscopic PD catheter placement include active abdominal infection and uncorrectable mechanical defects of the abdominal wall (+++Evidence, Strong recommendation)
2. History of prior abdominal surgery, regardless of how many, is not a contraindication to laparoscopic PD catheter insertion. It is appropriate for surgeons with experience in advanced laparoscopy to attempt lysis of adhesions and catheter placement in these patients. (++Evidence, Strong recommendation)
3. Patients with abdominal wall hernias should be diagnosed and repaired before or at the same time as PD catheter insertion. A repair should be chosen that minimizes peritoneal dissection and does not place mesh intraperitoneally (++Evidence, Weak recommendation)
4. PD may be initiated in patients with intraabdominal foreign bodies such as after open abdominal aortic aneurysm graft repair, but a 4 month waiting period is recommended. Very limited data exist regarding PD in the presence of an adjustable gastric band. (++Evidence, Weak recommendation)
5. PD may be safely initiated in patients with ventriculoperitoneal shunts (++Evidence, Weak recommendation)
6. Gastrostomy tubes can be used in pediatric patients on PD, though placement by blind percutaneous endoscopic technique (PEG) appears to be associated with higher infection rates compared to open insertion. (++Evidence, Weak recommendation)
7. Laparoscopic PD catheter insertion with carbon dioxide pneumoperitoneum requires general anesthesia. Patients who are high risk to undergo general anesthesia should be considered for a technique of catheter insertion that only requires local anesthesia and sedation, such as open insertion or fluoroscopically guided percutaneous insertion. Laparoscopic insertion using nitrous oxide pneumoperitoneum and local anesthesia is also an option where available. (++Evidence, Weak recommendation)

Indications

Patients are generally referred to a surgeon from a nephrologist for catheter placement once the decision is made to initiate PD. The indications for renal replacement therapy are found in the nephrology literature and are not within the scope of this guideline. Utilizing PD as a home therapy affords greater patient autonomy and quality of life than in-center hemodialysis (HD) [10]. Not surprisingly, patient satisfaction has been shown to be significantly higher in PD patients [10–12]. In addition, PD can be advantageous in the pre-transplantation period and prolong residual renal function compared to HD [13]. It also leads to a slight survival advantage during the first 2 years of renal replacement therapy and there is an improvement in anemia of kidney disease (significantly lower requirements of erythropoietin) [13]. However, there are no randomized controlled trials comparing the two modalities. Finally, PD may be favored in patients with vascular access failure, intolerance to HD, congestive heart failure, long distance from dialysis center, and peripheral vascular disease and bleeding diathesis [14]. PD may also be preferred by patients with the possibility of renal Transplantation in the near future, needle anxiety, and active lifestyle [14].

Absolute contraindications

The conditions below are considered absolute contraindications to PD catheter placement for renal replacement therapy. Novel uses like PD for treatment of edema in the open abdomen patient, or catheter placement for ascites management or intraperitoneal chemotherapy are not discussed and should be considered on a case by case basis.

1. Documented loss of peritoneal function such as ultrafiltration failure of the peritoneal membrane. [14, 15].

2. In the absence of a suitable assistant, impaired physical and mental ability of the patient to safely use the equipment on a daily basis, (severe active psychotic disorder, marked intellectual disability, poor home situation, impaired manual dexterity, and blindness) [14, 15].
3. Severe protein malnutrition and or proteinuria >10 g/day [14, 15].
4. Active intraabdominal, abdominal wall or skin infection which leads to high incidence of catheter infection by direct contact, such as active Crohn's disease, ulcerative colitis, and ischemic colitis. Frequent episodes of diverticulitis are also a contraindication since there may be an increased risk for transmural contamination by enteric organisms [14, 15].

Relative contraindications

There are certain conditions that are relative contraindications to PD catheter insertion or specifically laparoscopic insertion if there is a very high risk of complications or failure of dialysis to work.

1. Decreased capacity of peritoneal cavity

The peritoneal cavity must allow up to two liters of fluid to dwell at any time for PD to be effective. In pediatric patients, an exchange volume of 1,000–1,100 mL/m^2 BSA is recommended, though in infants and toddlers less than 2 years of age, this may be decreased to 800 mL/m^2 BSA [16, 17]. Women starting third trimester of pregnancy or patients with extensive abdominal adhesions that are not amenable to surgical correction do not have appropriate capacity of the peritoneal cavity for dialysate [15]. However, it is difficult to predict the degree of adhesions preoperatively. After abdominal surgery, adhesions between the omentum and abdominal wall occur in over 80 % of patients and involve the small intestine up to 20 % of the time [18]. In a sample of 436 patients who underwent PD catheter placement, Crabtree et al. reported the need for adhesiolysis in 32 % of those who had prior abdominal surgery (58 %), but only 3.3 % in those without prior abdominal surgery. It is not surprising that they found adhesiolysis was needed more commonly based on the number of prior operations, ranging from 22.7 % after one operation to 52 % if the patient had a history of four or more operations [19]. However, the severity of adhesive disease may only be evident after attempted lysis of adhesions and catheter placement as shown in his study where the incidence of catheter failure from extensive adhesions was only 1.8 %. In a similar study of 217 catheter insertions, Keshvari found a 42.8 % incidence of previous abdominal surgery and 27 % incidence of adhesions. Extensive laparoscopic adhesiolysis was required in only 3 patients. When comparing the patients who had adhesions and those without, he found no difference in the incidence of mechanical complications or need for revision [20]. Catheters have also been placed in a suprahepatic location in patients with a hostile pelvis precluding low placement of a catheter, and in infants undergoing open heart surgery with successful dialysis [21]. Therefore, history of prior abdominal surgery is not a contraindication to trying PD if surgeons with experience in advanced laparoscopy can attempt lysis of adhesions and catheter placement in these patients.

2. Lack of integrity of the abdominal wall

Uncorrected mechanical defects that prevent effective PD such as surgically irreparable hernia, omphalocele, gastroschisis, diaphragmatic hernia, pericardial window into the abdominal cavity, and bladder extrophy are also contraindications, although rare exceptions to this rule have been described [22]. The volume of dialysate must dwell in the abdomen where the peritoneum is well vascularized. Therefore, these conditions prevent proper PD and may lead to fluid leak into the pleural space or soft tissues. Because of the increased intraabdominal pressure with PD, the incidence of abdominal wall hernia is almost 30 % in adults and up to 40 % in children [23, 24]. Literature regarding giant abdominal wall hernia repair before or during PD is lacking. However, it is known that hernias can lead to complications such as dialysate leak, edema, pain, and incarceration all of which can prevent adequate dialysis. Therefore, a thorough examination for hernias is mandatory prior to PD catheter insertion and all hernias should be fixed before the initiation of PD. Furthermore, laparoscopy allows inspection and identification of occult inguinal hernias or patent processus vaginalis, which will inevitably become a clinical hernia in the future. Although no literature exits regarding concomitant hernia repair and insertion of PD catheter, many experts suggest fixing these defects when found. This may require consenting the patient for possible hernia repair prior to the laparoscopic insertion procedure. Comparative trials of open and laparoscopic inguinal hernia repair in PD patients do not exist. However, several reports have used open polypropylene mesh repair of inguinal hernias and shown very low recurrence and leak rates, despite resuming PD within a few days [25–28].

For ventral hernias, open anterior repair with inversion of the hernia sac without disrupting it, and placing onlay mesh has been shown to have low recurrence and leak rates in adults [29, 30]. If the peritoneum is entered, it is recommended to close the peritoneum in a water-tight manner [31]. Ventral and inguinal hernia repair may be performed concomitantly with PD catheter insertion and not delay the start of PD [32, 33]. If adequate hernia repair is not successful, there tends to be rapid enlargement and dialysate leak [34, 35], thus these patients may no longer be candidates for PD.

3. Obesity

Obesity is included in the National Kidney Foundation Kidney Disease Outcomes Quality Initiative Guidelines 2000 as a possible relative contraindication to PD. There are concerns that patients with high BMI may have inadequate solute clearance or ultrafiltration. There are also concerns about increased risk of catheter leak, exit site infection, and peritonitis. However this is not well studied in the literature. It is helpful to exit the catheter above the pannus, therefore the use of extended or pre-sternal catheters is useful in obese patients but this has not been studied in a randomized controlled trial [36, 37].

4. Intra abdominal foreign body

In patients with intra-abdominal foreign material such as vascular grafts and ventricular-peritoneal shunt, there is concern about an increased risk of contamination and graft infection [38]. However, the use of PD may offer considerable advantages in these patients including better hemodynamic control and avoidance of anti-coagulation. There have been three retrospective reviews that have shown no significant risk in using PD in patients with past history of open abdominal aortic aneurysm (AAA) repair [39–41]. In fact, in one study of 8 patients revealed that there were six episodes of peritonitis without clinical evidence of graft infection [39]. A review by Misra in 1998 concluded that “PD appears to be an efficient mode of dialysis with a surprisingly small number of complications in these patients” [42]. The National Kidney Foundation Kidney Disease Outcomes Quality Initiative Guidelines 2000 state that it is advised to wait 4 months after insertion of intra-abdominal foreign bodies, such as abdominal vascular prostheses [15]. This may become less of an issue with the emergence of endovascular AAA repair. There has been one published report of laparoscopic adjustable gastric band in the presence of PD. Valle et al. followed one PD patient with a Lap Band™ for 8 months and noted no infectious complications [43].

A survey of centers participating in the International Pediatric Peritoneal Dialysis Network identified 18 patients with concurrent ventriculoperitoneal shunts and PD catheters. In 15 of the 18 cases, the shunt was in place prior to placement of the dialysis catheter. The incidence of peritonitis was 1/19.6 months, which is quite similar to the 1/18.8 months reported in children without shunts [44]. More importantly, there were no episodes of meningitis or ascending shunt infections during episodes of peritonitis.

5. Ostomy

The presence of an ostomy has been considered by many a contraindication due to the possibly higher infection risk [15]. However, Korzets et al. has shown in a small number of adult subjects that mechanical and infectious complications are reasonably low [45]. Some authors have suggested using a pre-sternal exit site in adult and pediatric patients with stomas; however, this has not been studied in a randomized controlled fashion [37, 46, 47]. There is insufficient data to make a strong recommendation regarding PD in the presence of a stoma; therefore, that decision should be made on a case by case basis.

Gastrostomy tubes are commonly needed in pediatric patients with renal failure to improve nutritional status. A single center review of 90 pediatric patients on PD revealed 53.5 % had gastrostomy tubes with 60 % inserted prior to initiation of dialysis, 21 % after onset of PD, and 18 % inserted at the same time as the PD catheter. The infection rate was higher in patients with gastrostomy tubes (0.12 infections/month) as compared to those without (0.07 infections/month) independent of the timing of placement of the gastrostomy [48]. Placement of a percutaneous endoscopic gastrostomy (PEG) has been associated with an increased risk of peritonitis in children. A multicenter study identified 27 children who had a PEG tube placed in the setting of PD. Thirty-seven percent developed peritonitis within a week of placement and two led to death [49]. Ledermann et al. found no increase in infections in 9 children who underwent an open gastrostomy, but noted peritonitis in 4 of 5 children already on PD with PEG tube placement [50]. A recent study evaluated synchronous lap PD catheter placement with laparoscopic visualization during PEG placement and noted only one infection within the first month of placement in a cohort of 10 patients and no statistically significant increase in infections compared with 23 patients who had synchronous open gastrostomy tube placement [51]. Should a gastrostomy be required on pediatric patients already on PD, placement by blind PEG technique appears to have a higher infection rate and this should be considered against a potentially higher dialysate leak rate with open gastrostomy insertion.

6. Inability to tolerate general anesthesia

To achieve CO_2 pneumoperitoneum and visualization of the abdomen, general anesthesia was used in all the papers we reviewed using laparoscopic techniques except two published series using nitrous oxide pneumoperitoneum and local anesthesia [52, 53]. Patients with end stage renal disease generally have multiple medical problems with high incidence of vascular and heart disease [54]. Their risk stratification should be performed pre-operatively as is routine for any laparoscopic operation under general anesthesia. In patients who are not medically cleared for general anesthesia, open and percutaneous insertion techniques, performed under local anesthesia with or without sedation should be preferred. Nitrous oxide pneumoperitoneum under local anesthesia is also an option where available.

Insertion options

Guideline recommendation

8. For peritoneal access, blind percutaneous, open surgical, peritoneoscopic, fluoroscopically guided percutaneous, and laparoscopic insertion procedures, when performed by experienced operators, are feasible and safe with acceptable outcomes. (+++Evidence, Strong recommendation)

Blind percutaneous

In 1968, Tenckhoff and Schechter described a percutaneous non-visualized method of catheter placement. Unfortunately, this was associated with a risk of bowel or vessel injury, as well as a high incidence of malpositioned catheters resulting in failure rates of up to 65 % at 2 years [55]. However, several other reports using the blind insertion technique have shown adequate results, with dysfunction and leak rates below 7 % [56–59] and a bowel perforation risk of 1–2 % [57, 59, 60]. Zappacosta had two bowel perforations in patients who had prior abdominal surgery and, therefore, began using percutaneous insertion only in patients who had never had abdominal surgery [56]. Aksu described percutaneous placement of 108 peritoneal catheters in 93 pediatric patients with need for removal for dysfunction in 14 % over the 10 year period of the study, but no cases of bowel perforation [61]. The advantages of this technique are that the catheter may be inserted at the bedside, ICU, or minor surgical suite under local anesthesia for emergent dialysis. Varughese has recommended that this technique should be used preferentially in low-risk patients (no prior abdominal surgery) in developing countries where cost is a major factor [62].

Open surgical

Open placement under direct surgical vision via mini-laparotomy was described by Brewer in 1972 [63] and as of 2006 was the most commonly used insertion technique. However, 2012 Centers for Medicare & Medicaid Services (CMS) data show that the estimated use of this technique is 27 % in the United States owing to the rise in laparoscopic insertion techniques. In 1990, Nicholson et al. compared closed (percutaneous) insertion ($n = 163$) and open surgical insertion ($n = 290$) through a midline incision. They found that catheter survival was significantly better after open insertion than by closed [64]. To improve the leak rate, Stegmayr described a paramedian incision for entry with muscle splitting and minilaparotomy. The catheter is introduced using a stylet and essentially blind insertion into the pelvis. A purse string is used to secure the peritoneum around the catheter to prevent leakage. The posterior and anterior fascia is also closed around the catheter. Of 114 patients undergoing catheter insertion using this technique there were no fluid leaks and a dysfunction rate of 4.4 % [65]. As of 2004, the about 85 % of PD catheters placed in children used the open technique [66]. Owing to the thinner abdominal wall, pediatric catheter placement is typically with a periumbilical midline skin incision but a paramedian fascial incision in the anterior rectus sheath. After spreading apart the muscle fibers, the posterior sheath is opened, with or without tunneling behind the rectus, and the catheter inserted over a stylet. A purse string suture is used to close the fascia around the catheter at both the anterior and posterior layers, if possible [67]. Omentectomy is commonly performed in the pediatric population and may be performed through either the umbilical or paramedian incision [66–68]. Since there is direct visualization of the peritoneum prior to insertion, it may be preferred as a way of avoiding bowel injury in patients who have had prior abdominal surgery [69]. A disadvantage over percutaneous insertion is the need for an available surgical team and operating room. An advantage over the laparoscopic technique which requires general anesthesia is that it can be performed under local anesthesia and conscious sedation. However, the main limitation is up to a 38 % incidence of drainage dysfunction [70]. Two major factors that may be involved in catheter dysfunction are inadequate placement of the catheter tip into the pelvis, which allows the catheter to migrate and become entrapped within the omentum, and the presence of intra-abdominal adhesions, which interfere with correct catheter placement and may cause the PD fluid to loculate [71–74].

Peritoneoscopic

In an attempt to improve catheter function and decrease complications, a peritoneoscopic technique was described by Ash et al. in 1981 [75]. He used a special needlescope (Y-TEC, Medigroup, Inc. North Aurora, IL) with surrounding cannula and catheter guide. The steps of this insertion technique include: Needle trocar and surrounding Quill guide or sheath insertion through abdominal wall followed by insufflation using a hand pump and room air. A 2.5 mm scope is then advanced through the Quill guide. The operator peers through the lens and identifies an open space in the peritoneum, usually pelvis. The scope is removed, The guide is dilated to 6 mm and the PD catheter is inserted through it. The deep cuff is pushed through the Quill guide to a position below the anterior rectus sheath using a Cuff Implanter Tool (Medigroup Inc., Oswego, IL) and the guide is removed. The catheter is tunneled and pulled out a lateral exit site. This method reduced the early failure rate to 3 %

by the author. However, these results were not reproduced by Maffei who found a 12.5 % dysfunction rate in 119 patients [76]. Nahman et al. modified the insertion technique by entering the abdomen using a Seldinger technique with needle, wire then sheath and dilator, prior to inserting the scope. In a sample of 82 patients, the peritoneal cavity was successfully cannulated in 97.6 %. He found a leak rate of 4.9 % a dysfunction rate of 6.1 % and one patient who had ileal erosion and perforation [77]. Peritoneoscopic insertion is commonly performed by Nephrologists in an outpatient setting or in the ICU, and most of the recently published data are from outside the United States [78–80]. One quoted advantage is not having to involve a surgeon, operating room, or anesthesiologist. This has been shown to be very important in some countries where surgical support is lacking [81]. Having a dedicated team of interventional nephrologists to place PD catheters can increase the penetration of PD [80]. Another benefit is visualization of the peritoneum and more exact placement of the tip of the catheter than with blind percutaneous or open surgical. However, this technique does not allow for adhesiolysis, requires specialized equipment and expertise and has a risk of vascular and bowel injury on insertion [82]. Its use has fallen to less than 1 % in the United States as of 2012.

Fluoroscopically guided percutaneous

Fluoroscopically guided percutaneous PD catheter insertion has been reported in several large studies over the last decade and is another viable option depending on local expertise. A needle (blunt tip or Veress) is used in the left lower quadrant, often under ultrasound guidance to avoid the inferior epigastric artery [83]. A wire is inserted and guided into the pelvis under fluoroscopy. A sheath and dilator is then placed, followed by the catheter. The distal cuff is placed in the rectus sheath and the catheter is tunneled and brought out a separate stab incision. Several retrospective reviews have shown similar complication rates to open surgical insertion with failure rates between 0 and 5 % [84–87]. However, most of these studies only included patients who have never had abdominal surgery. The advantages of this technique are that it avoids the potential longer waiting times for surgical insertion, as well as the higher cost of an operating room and risk of general anesthesia. There is also potentially less trauma to the patient. The disadvantages are no direct visualization of the peritoneal cavity or lysis of adhesions, therefore, potentially poorer outcomes in patients who have had prior abdominal surgery [85, 88].

Laparoscopic insertion

Laparoscopic insertion of PD catheters was first described in the early 1990s, and the safety and feasibility of various laparoscopic insertion techniques in both adults and children have been documented in many case reports, retrospective reviews, and comparative studies [52, 68, 89–121]. Its use has grown steadily and it is now the technique used in about 50 % of PD catheter insertions according to CMS data. The early reports employed pneumoperitoneum and laparoscopy to visualize the catheter as it is inserted into the peritoneum and this has been referred to as "basic laparoscopic technique" in the literature. Subsequent reports used two- or three-port techniques to perform lysis of adhesions during insertion and manipulate the catheter tip into the pelvis [111, 122]. Perhaps the greatest benefit of laparoscopy in these cases is to facilitate adjunct techniques to help minimize catheter dysfunction. The primary causes of catheter dysfunction are compartmentalization from adhesions, catheter tip migration into the upper abdomen, and omental wrapping or entrapment. To directly address these issues, others began incorporating suture fixation of the catheter or rectus sheath tunneling to prevent migration and omentopexy or omentectomy to keep the omentum away from the catheter tip. The use of these measures has been referred to as "advanced laparoscopic techniques" and will be detailed next [115].

Advanced laparoscopic techniques to avoid catheter dysfunction

Guideline recommendation

9. Laparoscopic lysis of adhesions should be incorporated to reduce catheter dysfunction. (+++Evidence, Strong recommendation)
10. Laparoscopic suture fixation of the PD catheter may reduce catheter dysfunction but additional evidence is needed. (++Evidence, Weak recommendation)
11. Rectus sheath tunneling helps prevent migration and may be superior to suture fixation since it does not require added ports and instruments. (++Evidence, Weak recommendation)
12. Omentopexy in adults is a safe adjunct to laparoscopic PD catheter insertion and should be incorporated either routinely or selectively to reduce catheter dysfunction. (+++Evidence, Weak recommendation)
13. Omentectomy should be considered in pediatric patients undergoing PD catheter placement (++Evidence, Weak recommendation)
14. The combination of lysis of adhesions, rectus sheath tunneling, and omentopexy in combination offers the lowest rate of postoperative PD catheter dysfunction and should be a preferred technique in adults. (+++Evidence, Strong recommendation)

Lysis of adhesions

Peritoneal adhesions, usually from prior surgery are a major factor in PD catheter dysfunction due to compartmentalization of the peritoneal cavity. The laparoscopic approach allows identification and lysis of critical adhesions, although it may involve adding another one or two ports [90, 123]. Lysis of adhesions can be performed using ultrasonic shears if bleeding is a risk, or cold scissors [88]. It was employed in nine out of the ten large case series we reviewed [95, 106–111, 114, 124] and has been shown by Crabtree and Keshvari to allow similar catheter function rates in patients who have had abdominal surgery as those with a virgin abdomen [19, 20]. Although no studies specifically compared PD catheter placement and lysis of adhesions to PD catheter placement alone, lysis of adhesions is considered essential in decreasing catheter dysfunction.

Suture fixation

The intraperitoneal portion of the catheter functions best when in the pelvis. Therefore, catheter tip migration away from the pelvis is a common reason for catheter failure [71]. One way to prevent migration is suturing of the catheter tip to the bladder, uterus, or pelvic sidewall and this has been reported by several authors [91–93, 106, 107, 112, 124, 125]. This usually requires another trocar to place the suture. There have been, however, reports of suture fixation preventing easy catheter removal as well as being a potential cause of internal hernia or adhesions [126]. It may also impair the natural ability of the catheter to “float” to the largest area of PD fluid. Bar-Zoar and Lu showed a relatively high dysfunction rate after suture fixation of 14 and 12 %, respectively [107, 124]. However, Ko reported a 2.6 % migration rate [106] and Soontrapornchai compared 50 patients who had open surgery with 52 patients who had laparoscopic insertion and suture fixation to the pelvis sidewall. He showed 12 % migration rate with open and none with laparoscopic, although the dysfunction rates were 4 and 6 %, respectively [112]. In a review article by Frost et al., it was recommended that “proper rectus sheath tunneling and placement of the deep cuff are the key to reducing catheter tip migration” (not suture fixation) [126]. However, randomized trials comparing catheter insertion with and without suture fixation or comparing suture fixation to rectus sheath tunneling have not been performed.

Rectus sheath tunneling

Rectus sheath tunneling, also described as extraperitoneal or preperitoneal tunneling, has been used by many authors as a way to maintain a pelvic orientation and prevent catheter migration [52, 108, 110, 113, 127]. The technique involves visualizing the insertion device (sheath, blunt trocar or grasper) as it comes through the rectus muscle but before it enters the peritoneal cavity. Once the device is seen just above the posterior rectus sheath and peritoneum, it is tunneled 4–6 cm toward the midline pelvis before actually penetrating and entering the peritoneal cavity. Some have advocated suture fixation around the catheter at the anterior rectus sheath to further inhibit fluid leak [113]. This long tunnel can prevent movement of the tip to the upper abdomen and has been shown to decrease fluid leak. In addition, this technique has the advantage over suture fixation of not requiring extra trocars for suturing. Five studies using laparoscopic insertion and rectus sheath tunnel showed dysfunction rates between 4 and 8.6 % and leak rates from zero to 12.5 % [52, 108, 110, 113, 127].

Omentopexy and omentectomy

The omentum has been a known source of catheter dysfunction [74]. During the era of open surgery, omentectomy was described in adults and children as a way to reduce this complication. The omentum was pulled up through the incision and excised. Instead of removing omentum, McIntosh sutured it to the upper abdominal wall as omentopexy [128]. Although it is possible to do omentectomy during laparoscopic PD catheter insertion [97, 125], it adds to the procedure time, requires a larger incision and has a risk of bleeding [95]. Therefore, omentopexy seems to be favored in the literature. Laparoscopic omentopexy has been used routinely by Ogunc [94, 114, 127] or selectively by Crabtree, Attaluri and Haggerty in cases where the omentum extends into the pelvis [95, 113, 129, 130]. Omentopexy techniques include an anchoring suture in the upper abdomen using a transabdominal suture passer, anchoring sutures to the right and left upper abdominal wall using intracorporal suturing, and using a permanent tacking device to the abdominal sidewall. Goh described an omenal folding technique where the omentum was folded onto itself in a cephalad direction using silk sutures, shortening it [131].

The pediatric literature recognizes that catheter occlusion due to omental wrapping is more common in children than in adults [132]. A survey of 156 pediatric surgeons in 2004 revealed routine omentectomy was performed by 59 % of respondents [66]. Two smaller studies found decreased catheter occlusion rates in children with omentectomy (4.5 and 19 %) than in those without omentectomy (22.7 and 36 %, respectively), but these did not reach statistical significance [133, 134]. A larger study with 207 pediatric patients noted on multivariate analysis that lack of omentectomy was associated with nearly double the reoperative rate for infection or malfunction [135]. An additional review of 163 children with PD catheters revealed a significant reduction in catheter failure rate from 23 to 15 % when omentectomy was performed [136]. A study of 26 pediatric patients undergoing laparoscopic catheter placement revealed catheter survival in the 9 patients undergoing omentectomy was 8 months, compared to 5.8 months in those retaining their omentum. However, statistical analysis was not performed to determine the significance [125]. Based on this data, omentectomy should be considered in pediatric patients undergoing PD catheter placement.

Combined techniques

Both Ogunc and Crabtree have published dysfunction rates of zero and 0.5 %, respectively, when using rectus sheath tunneling and omentopexy [115, 127]. Furthermore, after incorporating rectus sheath tunneling and selective omentopexy for all laparoscopic PD catheter insertions, Attaluri found a primary dysfunction rate of 4.5 % in 129 patients using a combination of techniques versus 36.7 % when using basic laparoscopy [113]. Although high quality evidence is lacking, there is no added risk and in limited studies, significant benefit in combining lysis of adhesions, omentopexy and rectus sheath tunneling when performing laparoscopic PD catheter insertion.

Perioperative considerations

Guideline recommendation

15. Pre-surgical assessment should include thorough examination for hernias and the catheter exit site should be marked before surgery. (+Evidence, Weak recommendation)
16. A need for preoperative bowel preparation has not been conclusively demonstrated and further evidence is needed before a recommendation can be provided
17. Prophylactic antibiotics should be used prior to laparoscopic insertion of PD catheter. Vancomycin may be superior to first generation cephalosporins in minimizing early peritonitis after PD insertion. However its routine use should only be considered based on local resistance patterns and outcomes. (+++Evidence, Strong recommendation)

Pre-surgical assessment

Pre-surgical assessment of a patient undergoing laparoscopic insertion of a PD catheter should include thorough exam searching for hernias since these may be repaired at the time of insertion. Marking the exit site with the patient sitting or standing has been suggested in Clinical Practice Guidelines for Peritoneal Access in the United Kingdom and Flanigan's update on the ISPD Guidelines toward optimal peritoneal access [69, 137]. These recommendations were formulated by a panel of experts. In addition, the use of stencils to mark the exit site while patients were sitting, standing and lying has been reported to decrease the incidence of cuff extrusion [138].

Bowel preparation

The use of bowel preparation prior to laparoscopic insertion of PD catheters has not been studied well. Given that constipation is a known cause of catheter dysfunction, to optimize peritoneal access an evening laxative prior to surgery has been suggested [137].

Antibiotics

Pre-operative prophylaxis with intravenous antibiotics is recommended for PD catheter insertion by the International Society of peritoneal dialysis (ISPD) Guidelines for PD-related infections and European Best Practice Guideline for PD [139, 140]. A systematic review of 4 randomized controlled trials concluded that the use of perioperative intravenous antibiotic prophylaxis compared with no treatment significantly reduced the risk for early peritonitis (<1 month from insertion: 335 patients; RR, 0.35; 95 % CI, 0.15–0.80) but not the risk of exit-site and tunnel infection. It has been recommended that a single dose of first or second generation cephalosporin be given and that vancomycin not be used routinely to avoid development of vancomycin resistant enterococcus [137]. However, a subsequent randomized controlled trial by Gadallah and others that compared three preoperative antibiotic regimens found that during the first 14 days, peritonitis developed in 1 patient (1 %) in the Vancomycin group compared to 12 patients (12 %) in the control group (no antibiotics; $p = 0.002$), and in 9 patients (9 %) in the Cefazolin group ($p = 0.68$ compared to control group). Current clinical practice guidelines from the International Society of PD and Guidelines from a UK working group have recommended that Vancomycin be considered for prophylaxis based on local outcomes, weighing the potential benefits versus the risk of selection of resistant organisms and development of clostridium difficile colitis [69, 139].

Surgical technique

Guideline recommendation

18. Peritoneal access during lap PD insertion should be obtained away from previous scars; surgeons should use

the technique they are most comfortable and experienced with. (++Evidence, Weak recommendation)

19. The surgeon should minimize the size and number of ports used and place them in a manner that optimizes visualization of the catheter peritoneal insertion point and the pelvis. (++Evidence, Weak recommendation)
20. When inserting the PD catheter through the abdominal wall, the deep cuff should be placed inside the rectus sheath. (++Evidence, Strong recommendation).
21. The superficial PD catheter cuff should be 2 cm from the skin exit site in children and at least 2 cm in adults to prevent future cuff extrusion. (+Evidence, Weak recommendation)

Peritoneal access

Access to the peritoneal cavity has been accomplished by open Hassan trocar, subcostal Veress needle insertion or supraumbilical Veress needle insertion with equal efficacy. In patients with prior abdominal incision, closed access away from the midline or open technique is recommended for safety. In a review by Crabtree, he noted that 43 % of authors used a periumbilical site. He recommended avoidance of the umbilical access point due to the risk of hernia and the possibility of poor visualization when the camera is too close to the insertion point [88]. From the available literature, we conclude that access should be gained at the discretion of the operating surgeon

Equipment

Standard laparoscopes of thirty degree, zero degree, 3, 5 and 10 mm have all been used in the studies reviewed. There is no standard number of ports as one, two and three port techniques have been described of various sizes and types. Graspers and scissors should be available as well as ultrasonic dissecting instruments since lysis of adhesions is often necessary. Omentopexy requires a suture passing needle such as Endoclose ™ (Covidian, Norwalk, CT), Carter-Thompson device or laparoscopic suturing equipment and nonabsorbable suture. Mini-laparoscopic instruments have also been used with equal success [95, 127, 141–143]. Despite the paucity of publications comparing leak rates and the size of trocars, most authors recommend the smallest ports available in a non-cutting variety to allow the quickest healing of the peritoneum, thus facilitating early start of PD and low leak rate.

Catheter options

Commonly used catheters are silicone and have a pig tail or straight configuration internally. Pig tail catheters tend to be favored more in adults than children. Furthermore, they usually have two cuffs to prevent dislodgement and infection [139]. However, single cuff catheters are used selectively in small infants. Recommendations regarding the exact type of catheter to use are not within the scope of this guideline.

Trocar position

In both adult and pediatric patients, trocar position varied among the papers reviewed. Generally one port is used for the camera in the mid or upper abdomen and at least one more lateral port is used for grasping instruments. Minimizing ports may decrease the dialysate fluid leak but this has not been studied in randomized controlled trials.

Insertion through the abdominal wall

With regards to the insertion of the catheter through the abdominal wall, there are many choices. Some have used a 10 mm trocar usually with a purse string and the catheter is pushed in or pulled out with a grasping instrument. The 8 mm Step Trocar System (Covidian, Norwalk, CT) has been used extensively as it's diameter allows the cuffed catheter to slide through and then the trocar is removed [110, 113]. Others use a peel apart sheath and dilator (Quinton, Tyco Healthcare Group LP, Mansfield, MA) or a Quill catheter guide and cuff implanter (Medigroup corp. Oswego Illinois). During the implantation the deep cuff is placed in between the anterior and posterior rectus sheaths. Most, but not all authors continue to place a fascial pursestring suture around the catheter in pediatric patients to decrease the incidence of leak [67, 89, 121, 144].

Exit site and subcutaneous tunnel

After the deep cuff is placed, the end of the catheter is tunneled subcutaneously to an exit site in the lateral abdominal wall. Directing the tunnel inferiorly has been shown to possibly reduce the risk of catheter-related peritonitis in adults and children [139]. Pre-sternal exit sites have been described for children and adults with stomas, incontinence, obesity or other body habitus concerns [36, 47]. In adults, care is taken to make sure the superficial cuff is 2 cm or greater from the exit site to prevent cuff extrusion in the future [88, 139]. In children, it is placed at 2 cm [144]. In adults and children, suturing the catheter to the skin is discouraged due to risk of inflammation and infection. However, the catheter should be anchored close to the exit with either a dressing or commercially available immobilization device until fibroblast ingrowth at the Dacron cuff can sufficiently fixate the catheter (minimum 2–3 weeks) [144].

Intraoperative catheter trial

At the completion of the catheter implantation, it is standard to perform an intraoperative catheter trial to document adequate inflow and outflow. Between 250 mL and 1,000 mL in adults and 10 mL/kg in children were used in the literature [95, 111, 145].

Postoperative protocol

22. Minimizing dressing changes and handling may be beneficial in the first two postop weeks. (+Evidence, Weak recommendation)
23. Adequate time should be given after surgery for healing before PD is initiated and the current standard is 2 weeks. A more urgent start should be considered when the benefits outweigh the risks (++Evidence, Weak recommendation)

Dressings

The European best practice guideline for PD and the consensus guidelines for the prevention and treatment of catheter-related infections and peritonitis in pediatric patients receiving PD recommend that a dressing should be placed at the time of surgery and maintained throughout the healing phase. The dressing should not be changed more than once a week during the first 2 weeks unless bleeding occurs or infection is suspected [140, 144].

Optimal time to start dialysis

The timing of commencement of dialysis after catheter insertion has not been studied in randomized controlled trials, although one is currently underway in Australia [146]. Based on level three and four evidence, the Kidney Health Australia Caring for Australisans with Renal Impairment (CARI) guidelines suggest that "when possible, PD should not be commenced until at least 2 weeks after the insertion of the dialysis catheters" [147]. The ISPD and European dialysis and transplant association-European renal association also suggest a 2 week healing time prior to starting PD for both adults and children [69, 148]. However, urgent start (less than 2 weeks) PD is gaining popularity in the United States. In a study of 18 urgent start patients versus 9 non-urgent start patients, there was not a statistically significant difference in minor or major leak rates, although the urgent start group had two versus zero major leaks [149]. In a randomized controlled trial by Song et al. after blind percutaneous insertion the early leakage rates were similar (9.5 vs. 10.5 %) between immediate start PD with 2 Liters of dialysate and delayed start with gradual increase in fluid volume [150].

Adult outcomes

The primary outcome measure in our review is early and late dysfunction requiring removal or surgical repositioning. Dialysate leak is a common secondary outcome. We also compared perioperative complications such as bleeding and perforation which may vary based on the insertion technique. Outcomes from large series in adults using various techniques are presented in Table 3. In the following section, comparative studies are discussed in detail.

Summary of outcomes by surgical procedure

A summary of outcomes by surgical procedure is presented in Table 4

24. Blind percutaneous PD catheter insertion has acceptable malfunction and leak rates compared with open insertion in patients who have never had prior abdominal surgery. The technique may be especially useful in high-risk patients for general anesthesia as it can be performed at the bedside, under local anesthesia by trained nephrologists. However, bowel perforation and bleeding risk should be considered (+++Evidence, Weak recommendation)
25. Open surgical insertion continues to be a standard to which others are compared. It is safe (low perforation rate) and effective and can be performed under local anesthesia and sedation. It appears to have higher leak and dysfunction rates compared to image guided percutaneous and advanced laparoscopic insertion. (+++Evidence, Weak recommendation)
26. Peritoneoscopic insertion is a technique used worldwide, mostly by "interventional" nephrologists. It has been studied in patients who have had prior surgery, but there is at least a 1 % perforation rate. It appears to be comparable to open surgical insertion in experienced hands, but has not been compared to laparoscopic and fluoroscopic guided percutaneous insertion. (++Evidence, Weak recommendation)
27. In patients without prior abdominal surgery, percutaneous fluoroscopic PD catheter insertion results in similar or better complication rates and dysfunction rates compared to open or basic laparoscopic insertion, and avoids general anesthesia. (+++Evidence, Weak recommendation)
28. Basic laparoscopic insertion without using techniques to minimize catheter dysfunction results in similar

Table 3 Outcomes from large series in adult patients

Insertion technique	Author	Year	No.	Prior surgery	Dys-function	Leak	Bleeding	Perforation
Blind percutaneous	Zappacosta [56]	1991	101	Excluded	4 %	3 %	0	2 %
	Mellotte [60]	1993	50	Not stated	12 %	20 %	6 %	0
	Allon [59]	1998	154	Excluded	6.5 %	5 %	0	0
	Napoli [57]	2000	451	Not stated	6.7 %	6.8 %	3 %	1.5 %
	Banli [58]	2005	42	Excluded	4.8 %	4.8 %	0	0
Open surgical	Rubin [70]	1982	123	Not stated	38 %	20 %	0	0
	Robison [151]	1984	173	Not stated	6 %	5 %	0	0
	Bullmaster [72]	1985	115	Not stated	19.1 %	7 %	0	0
	Cronen [71]	1985	110	Not stated	22 %	12 %	0	0
	Stegmayr [152]	1993	114	Not stated	4.4 %	1 %	0	0
Peritoneoscopic	Adamson [153]	1992	100	14 %	4 %	7 %	3 %	1 %
	Nahman [77]	1992	82	Not stated	6 %	4.9 %	0	1.2 %
	Copley [154]	1996	136	Not stated	7.4	3.7	0	0
	Kelly [79]	2003	40	Not stated	2.5 %	2.5 %	0	0
	Goh [80]	2008	91	Not stated	17.6 %	NR	0	0
Fluoro-guided percutaneous	Zaman [155]	2005	36	Not Stated	3 %	3 %	3 %	0
	Vaux [84]	2008	209	Excluded	7 %	5 %		0
	Moon [86]	2008	134	Excluded	1.5 %	3 %	0.7 %	0
	Reddy [87]	2010	64	Not Stated	4.7 %	1.6 %	0	0
Basic laparoscopic	Poole [111]	2000	53	Included	2 %	2 %	2 %	2 %
	Draganic [117]	2001	30	50 %	3.3	3.3 %	0	0
	Gajjar [120]	2007	45	31 %	2.3 %	11 %	0	0
	Maio [109]	2008	100	9 %	6 %	5 %	0	0
	Jwo [119]	2010	37	10.8 %	11 %	18.9 %	0	0
Advanced laparoscopic[a]	Tsimoyiannis [156] (s)	2000	25	Included	0	0	0	0
	Lu [124] (s)	2003	148	Not stated	14 %	0	5 %	0
	Soontrapornchai [112] (s)	2005	50	Excluded	6 %	2 %	2 %	0
	Bar-Zoar [107] (s)	2006	34	26 %	11.6 %	3 %	0	0
	Schmidt [108] (t)	2007	47	Not stated	6.4	12.8 %	0	0
	Haggerty [95] (o)	2007	33	60 %	6.5 %	0	0	0
	Ko [106] (s)	2009	38	Included	0	0	0	0
	Keshavari [52] (t)	2009	175	Not stated	8.5 %	7.4 %	0.6 %	0
Advanced laparoscopic[b]	Crabtree [110]	2009	428	57 %	3.7 %	2.6 %	0	0
	Attaluri [113]	2010	129	Included	4.6 %	0	0	0
	Ogunc [127]	2005	44	20.5 %	0	0	0	0

Dysfunction—defined as catheter dysfunction requiring removal, replacement or revisional surgery

t rectus sheath tunnel, *s* suture fixation, *o* omentopexy

[a] Incorporating lysis of adhesions and either catheter fixation or omentopexy

[b] Incorporating lysis of adhesions, rectus sheath tunnel and omentopexy

dysfunction rates as open insertion. (+++Evidence, Strong recommendation)

29. Advanced laparoscopic PD catheter insertion using lysis of adhesions, catheter fixation preferably with rectus sheath tunnel, and omentopexy performed in combination has the lowest reported rate of catheter dysfunction in adults, even in patients with prior abdominal surgery. (+++Evidence, Strong recommendation)

Blind percutaneous vs. open surgical

Mellotte carried out a retrospective review in 1993 comparing percutaneous insertion of 50 PD catheters versus 180 catheters placed using open surgery. The percutaneous catheters were placed on urgent basis in patients not fit for anesthesia. That group had significantly higher leak rates 20 vs. 9.3 %, $p < 0.05$ and higher catheter dysfunction 12

Table 4 Summary of outcomes in adults

	Papers	Prior surgery	Dysfunction (%)	Leak	Perforation
Blind percutaneous	5	Excluded 3/5	4–12	3–20 %	0–2 %
Open	5	Not stated	4.4–38	1–20 %	0
Peritoneoscopic	5	0–14 %	2.5–17.6	3–4.9 %	0–1.2 %
Fluoro-guided percutaneous	5	Excluded 2/5	1.5–7	1.6–5 %	0
Basic lap	5	9–50 %	2–11	2–18.9 %	0–2 %
Advanced lap suture fixation	5	0–26 %	0–14	0–12.8 %	0
Advanced lap tunnel	2	Not stated	6.4–8.5	7.4–12.8 %	0
Advanced lap, tunnel and omentopexy	3	0–60 %	0–4.6	0	0

vs. 5.6 %. Bleeding and exit site infection was similar and they concluded that percutaneous PD catheter placement is safe and reliable and especially suited for ill patients who would not tolerate general anesthesia [60]. Another retrospective review of 215 PD catheter insertions by Ozener was published in 2001. One hundred thirty three were placed percutaneously by nephrology staff while 82 were placed by surgeons using an open technique. Patients with prior abdominal surgery were not considered for PD. They found similar complications in these two groups, (catheter malfunction 8.86 vs. 12.63 %, $p = 0.12$) [157]. In 2012, Medani published a retrospective analysis of 313 PD catheters placed surgically ($N = 162$) and percutaneously ($N = 151$). Patients with a history of abdominal surgery other than appendectomy or cesarean section were not candidates for the blind percutaneous insertion method. They found no statistically significant differences between the groups in poor initial drainage (9.9 vs. 11.7 %, $p = 0.1$) or secondary drainage failure (7.9 vs. 12.3 %, $p = 0.38$). However, they did find more exit site leaks in the percutaneous groups (20.55 vs. 6.8 %, $p = 0.002$) [158]. In summary, blind percutaneous PD catheter insertion has acceptable malfunction and leak rates compared with open insertion in patients who have never had prior abdominal surgery. The technique may be especially useful in high-risk patients for general anesthesia as it can be performed at the bedside, under local anesthesia by trained nephrologists. However, bowel perforation and bleeding risk should be considered.

Peritoneoscopic vs. open surgical

A prospective non-randomized study comparing open surgical insertion versus peritoneoscopic was performed by Pastan in 1991 on a total of 88 patients. He found no significant difference in early and late leaks and exit site infections. The catheter survival was significantly longer in the peritoneoscopic group. Reasons for removal were catheter dysfunction and infection requiring removal and no differentiation was made between the two [159]. Gadallah conducted a randomized controlled trial comparing the outcome of 76 patients in whom the PD catheters were placed peritoneoscopically with that of 72 patients in whom the catheters were placed surgically. Early peritonitis episodes (within 2 weeks of catheter placement) occurred in 9 of 72 patients (12.5 %) in the surgical group, versus 2 of 76 patients (2.6 %) in the peritoneoscopy group ($p = 0.02$). This higher rate of infection was most likely related to a higher exit site leak in the surgical group (11.1 %) as compared with the peritoneoscopy group (1.3 %). Moreover, peritoneoscopically placed catheters were found to have better survival (77.5 % at 12 months, 63 % at 24 months, and 51.3 % at 36 months) than those placed surgically (62.5 % at 12 months, 41.5 % at 24 months, and 36 % at 36 months) with $p = 0.02$, 0.01, and 0.04, respectively [160]. In contrast, Eklund reviewed 108 catheters in a non-randomized study of 65 patients having PD catheter insertion using peritoneoscopic techniques versus 43 using open surgical techniques. He found a higher rate of incorrect placement and omental obstruction (4.6 vs. 0 %) and leakage (13.8 vs. 2.3 %) in the peritoneoscopic group. They concluded that surgically placed PD catheters appear to have a longer survival time than peritoneoscopically placed ones [78]. In summary, peritoneoscopic insertion is a technique used worldwide, mostly by "interventional" nephrologists. It has been studied in patients who have had prior surgery, but there is at least a 1 % perforation rate. In experienced hands, it appears to have similar if not better outcomes compared to open surgical insertion, but has not been compared to laparoscopic or fluoroscopic guided percutaneous insertion.

Open vs. fluoroscopic guided percutaneous placement

The largest retrospective cohort analysis comparing open surgical insertion to fluoroscopically guided percutaneous insertion in 101 patients, revealed no significant difference in complications or catheter malfunction. However, this series only included patients with no prior abdominal surgery. The open surgical group $N = 49$ tended to have more complications than the percutaneous group $N = 51$; Leakage 13 vs. 4 %, $p = 0.093$, malfunction 11 vs. 9 %, $p = 0.73$ and bleeding 8 vs. 2 %, $p = 0.21$ [161]. One recent study compared open surgical insertion and percutaneous fluoroscopic in a randomized controlled trial and found no difference in 1 year catheter survival. It was not stated whether patients with prior abdominal surgery were excluded. The surgical group had significantly more bleeding complications (13.3 vs. 3.2 %, $p < 0.0001$). Early catheter malposition was similar in each group (6 %) but the late dysfunction rate due to omental wrapping was significantly higher in the surgical group (13.3 vs. 2.9 %, $p < 0.0001$). The mean operating time was also longer in the surgical group [162].

Basic laparoscopic vs. fluoroscopic guided percutaneous placement

Voss performed a randomized controlled trial comparing FGP catheter insertion vs. basic laparoscopic in 2012. Patients with obesity, previous abdominal surgery and history of adhesions were excluded. A total of 113 patients were randomized. They found a higher rate of early leakage in the surgery group at 1 year follow-up (17.9 vs. 7 %, $p = 0.08$). Rates of exit site and tunnel infections were similar but peritonitis was more common in the laparoscopic group. Dysfunction rates and catheter survival were similar while the laparoscopic group had almost twice the hospital cost [163].

To summarize, percutaneous fluoroscopic PD catheter insertion offers a low cost option of catheter insertion when experts are available. In patients without prior abdominal surgery, this method of insertion results in similar or better complication rates and dysfunction rates compared to open or basic laparoscopic insertion, and avoids general anesthesia. Randomized controlled trials comparing this to advanced laparoscopic insertion in patients without prior abdominal surgery are needed to clarify the best technique in these patients.

Open vs. basic laparoscopic

Two early retrospective studies comparing laparoscopic and open insertion of PD catheters showed a trend toward lower complications and dysfunction with the laparoscopic group, but did not reach statistical significance [117, 118]. A retrospective study by Gajjar comparing 30 open PD catheter placements to 45 simple laparoscopic placements and lysis of adhesions showed an immediate functional success of 97.8 % in the laparoscopic group versus 80 % in the open group ($p = 0.014$) even though 31 % of the laparoscopic patients had prior abdominal surgery versus 16 % of the open patients. The incidence of exit site leak was similar 11 vs. 13 % [120]. Wright et al. compared 24 patients using open insertion with 21 laparoscopic insertions in a randomized prospective trial. They found higher incidence of early fluid leak in the laparoscopic group 9.5 vs. 0 % and no difference in mechanical dysfunction. The incidence of prior surgery was 20.8 vs. 52 %, laparoscopic vs. open [116]. Furthermore, a prospective randomized study by Jwo comparing open insertion and insertion using basic laparoscopic techniques and lysis of adhesions showed an improvement in early migration with laparoscopy (2.7 vs. 15 %, $p = 0.110$) but higher late migration rates (8.1 vs. 2.5 %, $p = 0.346$). There was also a higher rate of pericannular bleeding in the laparoscopic group (21.5 vs. 7.5 %, $p = 0.077$ and similar rates of dialysate leak. They concluded that laparoscopic insertion was not cost effective and recommend conventional open surgery for most patients needing primary catheter placement [119]. A systematic review and meta-analysis by Xie in 2012 concluded that laparoscopic catheter placement has no superiority over open surgery. However, this study incorporated a trial in pediatric patients, trials using peritoneoscopic insertion and the above trials using basic laparoscopic techniques. They also concluded that “in the future, advanced laparoscopy using more sophisticated procedures may reduce complications in catheterization” [164]. There is a multicenter randomized controlled single-blind trial currently underway in Europe to compare laparoscopic versus open PD catheter insertion but it was not stated whether this incorporates advanced laparoscopic techniques [165].

Advanced laparoscopic techniques

In 2000, another randomized controlled trial comparing open insertion under local with three port laparoscopic insertion under general anesthesia. Their technique included suture fixation of the catheter to the bladder or peritoneum. Five of the laparoscopic patients underwent lysis of adhesions. They found that the mean operating time was longer in the laparoscopic group, 22 vs. 29 min, $p < 0.001$. More importantly, the rate of fluids leak and tip migration were significantly lower in the laparoscopic group (32 vs. 0 %, $p < 0.005$ and 20 vs. 0 %, $p < 0.005$) [156]. Ogunc in 2003 was one of the first to compare open surgery and laparoscopic insertion in 42 patients using omental fixation (omentopexy). He found a zero mechanical dysfunction rate with this technique versus 23.8 % after open insertion ($p < 0.05$). He concluded this was a successful method of preventing obstruction due to omental wrapping with a better catheter survival [114]. Likewise, Soontrapornchai compared 52 patients who underwent open insertion and 50 patients who had laparoscopic insertion with suture fixation of the tip of the catheter into the pelvis. He found that catheter dysfunction from migration was lower in the lap group (12 vs. 0 %, $p = 0.027$) but the operating times were longer (65 vs. 29 min., $p < 0.001$) [112]. In 2005, Ogunc published results from a prospective study of 44 consecutive patients who underwent laparoscopic PD catheter insertion using the combination of lysis of adhesions, rectus sheath tunneling and omentopexy. 20 % had a history of previous abdominal surgery and half of those required lysis of adhesions. PD was started within 24 h and there were no leaks, no episodes of dysfunction and no major complications after a median follow-up of 17.4 months [127]. Crabtree published a large comparative study of three groups. An open group ($N = 63$), a basic laparoscopic group, ($N = 78$) and an advanced laparoscopic group, ($N = 200$). This group incorporated rectus sheath tunneling as a way of preventing migration, selective omentopexy and selective lysis of adhesions. He found catheter obstruction rates of 17.5, 12.8 and 0.5 %, respectively ($p < 0.0001$). There were similar rates of pericannular leaks of about 2 % [115]. His findings were corroborated by a study of 197 patients by Attaluri at the Cleveland Clinic in 2010. In the advanced group of 129 patients, they used a 4–6 cm rectus sheath tunnel and selective omentopexy when the omentum was found to lie within the pelvis/retrovesical space (53.5 % of patients in their series). They found a 4.5 % primary dysfunction rate in this group versus 36.7 % in the 68 patients who had catheters placed without these additional measures ($p < 0.0001$). In addition, there was only one case of exit site leak (0.51 %) presumably due to the rectus sheath tunneling [113]. In summary, there has been no standardization worldwide regarding basic or advanced laparoscopic insertion of PD catheters. There is significant evidence that basic laparoscopic insertion results in similar dysfunction rates as open insertion. The addition of omentopexy has not been studied by itself but appears to lower the incidence of catheter dysfunction. Suture fixation and rectus sheath tunneling can limit migration and the latter requires less additional ports and instrumentation. Combining lysis of adhesions, catheter fixation with long rectus sheath tunnel, and omentopexy significantly reduces catheter dysfunction when compared to open insertion and basic laparoscopic insertion and appears to be the preferred technique in adults, especially in patients with prior abdominal surgery. However, well designed randomized controlled trials comparing advanced laparoscopic insertion to other techniques are needed to definitely answer the question.

Preferred insertion technique

Table 5 provides a summary of preferred insertion technique based on patient factors and assumes experts such as surgeons and interventional radiologists are available to perform the procedures. It is based on the level II and III evidence of our review.

Table 5 Preferred insertion technique in adults

	History of prior surgery or peritonitis Preferred insertion technique (in order of preference)	No history of prior surgery or peritonitis Preferred insertion technique (in order of preference)
Patient able to tolerate general anesthesia	Advanced laparoscopic	Advanced laparoscopic Fluoroscopic guided percutaneous[a] Open Surgical Peritoneoscopic Percutaneous
Patient only able to tolerate local anesthesia/sedation	Fluoroscopic guided percutaneous Open surgical	Fluoroscopic guided percutaneous Open surgical Peritoneoscopic Percutaneous

[a] High quality evidence is lacking comparing FGP to ALS PD catheter insertion in patients who have never had abdominal surgery

In practices where surgical access is limited, nephrologist and radiologist inserted catheters using percutaneous or peritoneoscopic techniques may be the best choice based on local equipment availability and operator expertise.

Pediatric outcomes

Outcomes from large series in pediatric patients are presented in Table 6.

Comparative studies in pediatrics

In the pediatric literature, there are multiple retrospective studies inclusive of patients who had open or laparoscopic PD catheter placement, all with the use of omentectomy in at least portions of the cohort. None of these reviews noted any significant decrease in reoperation for catheter dysfunction [68, 133, 135]. One study included 36 patients with laparoscopic placement and fixation in the pelvis to 23 patients with open catheter placement. Omentectomy was performed in 85 % of the laparoscopic and 65 % of the open patients. Similar rates of peritonitis, exit site infections, and catheter migrations were noted, though the time to catheter dysfunction was longer for the laparoscopic group (9 vs. 2.4 months) [170]. In a single, prospective, non-randomized series, catheter leakage occurred in five of 23 patients undergoing open placement and only two of 25 placed laparoscopically, with one of the two healing spontaneously. The only other complication reported was

Table 6 Outcomes from large series in pediatric patients

Insertion technique	Author	Year	No.	Prior surgery?	Dysfunction (%)	Leak	Bleed	Perforation
Blind percutaneous	Aksu [61]	2007	108	Not stated	24	NR	0	0
Open surgical	Stone [166]	1986	167	Not stated	6.1	14 %	0	0
	Macchini [167]	2006	89	Not stated	12	5.6 %	0	0
Peritoneoscopic	None							
Fluoro-guided percutaneous	None							
Basic laparoscopic	Stringel [168]	2008	21	23.4 %	18	NR	0	0
Advanced laparoscopic[a]	Milliken [89] (o)	2006	22	Not stated	4.5	4.5 %	0	0
	Numanoglu [125] (o,s)	2008	36	Not stated	38.8	5.5 %	2.8 %	0
	Subramaniam [169] (o)	2008	48	Not stated	10.4	6.2 %	0	0
Advanced laparoscopic[b]	None							

Dysfunction—defined as catheter dysfunction requiring removal, replacement or revisional

t peritoneal tunnel, *s* suture fixation, *o* omentectomy

[a] Incorporating lysis of adhesions and either catheter fixation or omentopexy/omentectomy

[b] Incorporating lysis of adhesions, peritoneal tunnel and omentopexy

outflow obstruction, occurring in two patients from both the laparoscopic and open groups. The authors concluded laparoscopic catheter insertion is at least equivalent, if not superior to open catheter placement in terms of function and operative complications [121].

Preferred insertion technique in pediatric patients

No insertion technique has emerged as a clear preference in pediatric patients. A 2004 survey of pediatric surgeons in 2004 revealed that only 14 % of surgeons used laparoscopy for insertion. However, increasing published series of laparoscopic placement of PD catheters in pediatric patients suggests increasing use of this technique for insertion.

Postoperative complications

A summary of postoperative complications is provided in Table 7

30. Bleeding after PD catheter insertion may occur from inferior epigastric artery injury or lysis of adhesions and should be managed according to standard surgical principals. The insertion point should be at the medial border of the rectus sheath to avoid arterial injury. Coagulation parameters should be assessed and corrected pre-operatively. (+Evidence, Weak recommendation)
31. Dialysate leaks after PD catheter placement may be amenable to treatment, and potentially prevention, with the use of fibrin glue, particularly in the pediatric population. (++Evidence, Weak recommendation.)
32. Exit site infection is managed by oral antibiotics. Chronic exit site and cuff infections may managed by catheter salvage consisting of unroofing the track, shaving the superficial cuff and using a new exit site. (++Evidence, Weak recommendation)
33. Pain during PD is a rare complication that is usually amenable to medical management but occasionally requires repositioning or removal of the catheter. (++Evidence, Weak recommendation)

Bleeding

Bleeding is a risk after laparoscopic PD catheter insertion occurring in 0–5 % of patients in our review. The catheter insertion site is through the rectus sheath and significant bleeding may occur from injury to the inferior epigastric artery [111, 124]. If identified should be managed by ligation during the procedure. Bleeding complications may also present as postoperative rectus sheath hematoma which may be managed non-operatively in selective cases. Omentectomy and lysis of adhesions may also predispose to postoperative intraabdominal bleeding [124]. Finally, bleeding may also occur at the exit site and may be controlled with direct pressure or sutures. Bleeding complications associated with PD catheter insertion may be associated with anticoagulation. Therefore, coagulation parameters should be checked and corrected preoperatively [171]. The use of dDDAVP has not been studied but may be helpful in a patient who develops a bleeding complication [171]. Techniques to avoid arterial injury include making the insertion site toward the medial border of the

Table 7 Early and late postoperative complications

Author	Year	Number	Early complications				Late complications			
			Bleeding (%)	Leak (%)	Visceral injury (%)	Exit site infection	Peritonitis	Cuff infection (%)	Dysfunction (%)	Pain
Crabtree [110]	2009	428	0.0	2.6	0.0	NA	NA	0.0	3.7	0.0 %
Keshvari [52]	2009	175	0.6	7.4	0.0	NA	NA	1.7	8.4	0.0 %
Lu [124]	2003	148	5.0	0.0	0.0	NA	11.0 %	18.0	14.0	NA
Maio [109]	2008	100	0.0	5.0	0.0	0.0 %	2.0 %	0.0	6.0	NA
Poole [111]	2000	48	2.0	2.0	0.0	2.0 %	8.0 %	0.0	2.0	0.0 %
Schmidt [108]	2007	47	0.0	12.8	0.0	2.1 %	10.6 %	0.0	4.3	NA
Ogunc [127]	2005	44	0.0	0.0	0.0	2.1 %	0.0 %	0.0	0.0	0.0 %
Ko [106]	2009	38	0.0	0.0	0.0	0.0 %	5.3 %	0.0	0.0	0.0 %
Bar-Zohar [107]	2006	34	0.0	2.9	0.0	14.7 %	NA	0.0	11.7[a]	0.0 %
Haggerty [95]	2007	33	0.0	0.0	0.0	3.0 %	6.5 %	0.0	6.5	3.2 %

[a] 8 other outflow obstructions were treated with urokinase

rectus sheath and using blunt trocars or sheaths to insert the catheter through the abdominal wall [113, 115].

Dialysate leak

Dialysate fluid leak is a known problem occurring in 0–12.8 % of patients after laparoscopic insertion of PD catheter. It can happen early (<30 days) or late (>30 days). Causes include Inguinal or abdominal wall hernias [35, 172], peritoneal tears [173], leaks around the dialysis catheter, trauma, fluid overload and malignancy [35, 174]. Early leaks commonly are from the catheter insertion site or surgical wound and may be related to insertion technique and/or the timing of the start of CAPD after surgery. After open surgery, paramedian insertion has shown to have lower leak rates compared to midline insertion in both adults and children [175, 176]. Low-leak rates have also been demonstrated after peritoneoscopic insertion [75] and laparoscopic insertion using a long peritoneal tunnel [113, 115]. However, there is no level I evidence to support one technique over another with regard to leak rates.

The treatment of fluid leak is an attempt at low volume or cycled PD. If this fails, the leak will usually respond to temporary transfer to HD for 2–4 weeks. If a hernia is detected as the cause it should be repaired using techniques discussed earlier in the guideline, usually without disruption of PD [26].

The incidence of dialysate leak has been noted to be higher (up to 18 %) in infants than larger patients, likely due to their thinner abdominal walls [135]. Rusthoven et al. reported the use of fibrin glue to the catheter tunnel exit site in 8 pediatric patients in whom dialysate leaks was seen in the first 24–48 h after catheter insertion. There was no recurrence of leakage and no exit-site, tunnel, or peritoneal infections developed [177]. Joffee reported success in sealing chronic leaks in 5 of 6 adult patients treated with 1 or 2 applications of fibrin glue, a cohort that would otherwise have had their catheter removed [178]. Success in sealing leaks led to one randomized, prospective trial of fibrin glue application to prevent leaks in pediatric patients. Sojo et al. randomized 52 catheter implantations to either standard implantation or application of 1 mL of fibrin sealant to the peritoneal cuff suture [179]. The incidence of catheter leakage was only 9 % in the sealant group, compared with 57 % in the control group, with no differences in the incidence of infections. Application of fibrin glue may be helpful in both preventing and sealing dialysate leaks, particularly in the pediatric population.

Visceral injury

Injuries to the small or large bowel are rarely described after lap PD insertion due to the direct visualization of the catheter insertion into the abdomen. Bowel injury may be possible during lysis of adhesion but that has not been identified in the adult literature.

Exit site and cuff infection

Infection of the skin at the catheter exit site or rarely the skin overlying the insertion site may be an early or late complication. The initial treatment is oral antibiotics. Exit site infections in the pediatric population are less likely to respond to antibiotics alone and surgical salvage may be needed. "Cuff shaving" by unroofing the subcutaneous cuff, shaving it off, and rerouting the catheter to an alternate exit site has been reported successful in 87.5 % of children in one study from Japan [180]. This technique was also successful in 13 adults with chronic tunnel infection [181] Wu et al. described 26 catheters in 23 patients in which the entire subcutaneous tubing was replaced from just above the internal cuff with no interruption in dialysis [182]. Salvage of the catheter by these techniques may be considered in select patients who fail antibiotic therapy.

Peritonitis

The incidence of peritonitis after lap PD catheter insertion has been reported between 0–11 % which compares to that of open insertion. Its management consists of intravenous and intreperitoneal antibiotics based on culture results. Catheter removal is indicated in refractory cases and fungal peritonitis.

Pain

Pain on instillation of PD fluid or draining is a known complication in patients undergoing PD. It is thought to be due to shearing forces against the peritoneum or "jet" effect of dialysate

Emerging from the distal end of the catheter at relatively high velocity. It can also be related to the pH of the dialysate. If the pain is on outflow, it may be due to suction effect and is often positional. Treatment includes altering the pH of the fluid, slowing down the infusion, or not completely draining the peritoneum at the end of dialysis (tidal dialysis) [183]. The pain may resolve with time, unfortunately if it is debilitating, catheter repositioning or removal may be necessary [184, 185].

PD catheter malfunction

Guideline recommendation

34. Malfunctioning PD catheters should be evaluated by physical examination and plain radiographs to rule out constipation. If negative, further studies such as catheterography or CT peritoneography, followed by diagnostic laparoscopy are indicated. (++Evidence, Weak recommendation)
35. Non-operative treatments of malfunctioning PD catheters which have been proven effective include flushing, thrombolytics and fluoroscopic wire manipulation. (++Evidence, Weak recommendation)
36. Patients with malfunctioning PD catheters not amenable to non-operative measures should undergo laparoscopy with catheter repositioning, adhesiolysis, omentectomy or omentopexy. Patency should be assured by stripping and flushing. Suture fixation of the catheter to the pelvis or polypropylene sling may be utilized to reduce catheter migration. Surgical techniques for catheter salvage require individualization based upon operative findings. (+++Evidence, Strong recommendation)

Catheter malfunction has plagued PD patients since the first catheter was placed in 1968. No insertion technique has been able to prevent this complication which is frustrating to patients and doctors alike. It causes an interruption in dialysis and requires multiple personnel to be involved. In fact, in one analysis, 19.6 % of 7,694 patients who transferred to HD from PD during the first year of therapy did so because of mechanical catheter issues [113, 186]. Mechanical failure occurs in 22–30 % of pediatric PD catheters [133, 135, 187]. Catheter malfunction, defined as insufficient inflow and/or outflow of dialysate, can occur for a variety of reasons. Catheter inflow problems may simply be due to catheter kinking external to the skin, or from internal catheter obstruction [188]. Early failure from catheter kinking may be related to surgical technical error. Inflow and outflow failure may be caused by intraluminal catheter obstruction due to a blood clot or a fibrin plug and this may be precipitated by low grade peritonitis. One of the most common causes of malfunction is compression of the catheter by distended colon due to constipation and this should be treated empirically when there is poor flow [8, 185]. Bladder distension from urinary retention can also decrease outflow. In addition, extraluminal occlusion of the catheter holes by fibrin sheath encapsulation, omental wrapping, peritoneal adhesions, or adjacent organs (small intestine, bladder, appendix, fallopian tube, etc.) will result in outflow failure. Finally, there can be compartmentalization of the peritoneal cavity by adhesions, or migration of the catheter tip outside of its dependent location in the pelvis which prevent adequate flow [8, 189–192]. In a registry of pediatric 503 dialysis catheters, failure was due to leakage in 5.8 %, dislocation in 5.8 %, obstruction in 5.3 %, and cuff extrusion in 4.8 % [187].

Evaluation

Comparative studies regarding the evaluation of malfunctioning PD catheters are lacking. However, evaluation should include physical examination and radiographic studies in an attempt to elucidate the cause [192]. Examination of the catheter external to the skin should rule out kinking or plugging. An algorithmic approach to the evaluation of catheter outflow failures has been described for the evaluation of poorly functioning catheters which includes inspection of the dialysis fluid appearance [191]. Cloudy fluid is sent for leukocyte count and culture to assess for peritonitis. Obstruction in the presence of clear dialysate warrants evaluation with an abdominal x-ray to assess for catheter tip dislocation or intestinal dilation from constipation. If constipation is deemed to be the cause, cathartics and enemas are used for treatment [193]. If the catheter tip is dislocated, wire manipulation may be attempted [8]. In the absence of abnormalities on x-ray, catheterography, or CT peritoneography is the next step. During catheterography, injection of water soluble contrast under fluoroscopy can assess catheter flow and loculation or compartmentalization of the tip [194, 195]. CT peritoneography is very useful in assessing malfunctioning PD Catheters. This test involves CT scanning after instilling a mixture of 2 liters of dialysate and 100 mL of non-ionic contrast agent. The patient is ambulated for 30–60 min prior to scanning [196]. It has been utilized with success to identify catheter-related complications and obstructions including peritoneal tear, fluid leak, peritoneal thickening, calcifications, loculated fluid collections, abscesses, hernias, hematomas and catheter malposition [197–200]. Diagnostic laparoscopy is also highly sensitive at diagnosing catheter dysfunction and revision can be employed at the same time [192].

Nonoperative management

The management of catheter malfunction should proceed from least to most invasive [192]. Constipation should be aggressively managed medically. Intraluminal obstruction due to blood clots or fibrin plugs may respond to manual compression of the dialysis bag or aspiration and forceful flushing with heparinized saline [192]. The use of fibrinolytic agents such as urokinase or TPA followed by forceful irrigation is also an option to remove clots and fibrin plugs in both adults and children [201–203]. Two publications report restoration of catheter function in 57 and 83 %, respectively [204, 205].

Wire manipulation under fluoroscopy may be utilized to reposition catheters that have either migrated or have become wrapped in omentum [206–213]. These techniques involve placement of a stiff-wire into the dialysis catheter under sterile conditions. Although most studies have utilized these techniques under fluoroscopic guidance, some authors have demonstrated successful catheter repositioning without radiographic assistance [214]. In a retrospective study of 140 patients who underwent PD catheter placement, there were 49 catheter failures in 33 catheters over the 13 year study period. In this study, catheter migration rates varied based upon catheter type with straight catheter migration rates of 54 % and swan-neck catheter migration rates of 31 %. Amongst those catheter failures that were treated with fluoroscopic manipulation with a stiff-wire, immediate catheter repositioning occurred in 54 % although only 29 % of catheters were successfully salvaged long-term. No complications occurred as a result of these catheter manipulations [215]. Another retrospective study of 203 patients demonstrated success rates following fluoroscopic catheter manipulation with a stiff-wire to result in success rates of 78, 51, and 25 % in the immediate, 1 week, and 1 month time frame following the intervention [210]. The success of fluoroscopic catheter manipulation has been demonstrated to be related to the orientation of the catheter tunnel at time of insertion. Those catheters that were placed through the abdominal wall with an angled tunnel directed toward the pelvis have the highest success rates with fluoroscopic manipulation [213]. Successful catheter salvage has also been demonstrated amongst patients requiring repeat wire-guided manipulations with secondary salvage rates as high as 63 % [212]. The utilization of a Fogarty balloon catheter placed through the lumen of the dialysis catheter has also been described to facilitate manipulation of the catheter under fluoroscopy [216]. In summary, wire manipulation has initial success rates of 64 to 86 % but longer term success (>30 days) is significantly lower (as low as 29 %).

Laparoscopy for malfunctioning catheters

In circumstances in which non-operative strategies fail to adequately address PD catheter malfunction, or the diagnosis is not clear, laparoscopic correction should be employed [8, 192, 217]. Numerous techniques have been described for salvage of malfunctioning PD catheters, although not all techniques are applicable in each circumstance [131, 217–221]. The specific cause of the catheter problem and the findings at laparoscopic exploration dictate the corrective action. Peritoneal access may be gained via Veress needle or open Hassan technique either in left upper quadrant or periumbilical area. Pneumoperitoneum may be obtained by insufflating through the existing PD catheter, thus avoiding any risk from insertion [221]. However, this technique may be unsuccessful if omental wrapping or compartmentalization of the catheter is present. The laparoscope may be introduced through a periumbilical port to diagnose the etiology of the malfunction. Additional 5 mm working ports are then placed to manipulate the catheter [131, 189, 191, 219, 222]. Postoperative leakage of dialysate from port sites has been reported, and this has prompted the preferential use of only 5 mm ports by some authors [220]. In addition, port placement through the linea alba has been implicated in postoperative leakage. As a result, placement of all ports in a location off-midline has been advocated [131]. In addition, the fascia should be closed with suture at all 10 mm port sites [220].

The most common findings at laparoscopic exploration are catheter tip migration with or without associated omental adhesions. Although most series are small, this is consistent across multiple reports [189, 219, 222, 223]. In one series of 40 patients who underwent laparoscopy for malfunctioning catheters, catheter tip migration was seen in 28, ten of which had associated omental adhesions. Two patients had catheter migration with adhesed bowel. Omental adhesions in the absence of catheter migration that resulted in a malfunctioning catheter were seen in 4 of these patients [189]. Thus, adhesiolysis and repositioning of the catheter are among the most commonly performed procedures in catheter revision. Adhesiolysis is generally performed by a combination of blunt and sharp dissection with judicious use of electrocautery. Simple stripping of omentum from the catheter is usually successful [219]. Once free, the catheter is flushed and closely inspected to assure patency. If fibrin plugging is present, the catheter may be stripped with blunt grasping instruments. If this does not work, the tip of the catheter can be exteriorized through one of the port sites to facilitate clearing [220, 222]. The catheter tip is then replaced into a proper dependent position within the pelvis. Many authors recommend anchoring the catheter tip within the pelvis using a suture. A "polypropylene sling," in which a suture passer is used to create a loop of nonabsorbable suture around the catheter has also been described. The transfascial loop of suture is placed about 5 cm distal to the insertion site towards the pelvis. This maintains the catheter in a caudal direction, helping to prevent future migration [131]. Data are insufficient to comment on the effectiveness of this technique in preventing recurrent catheter migration. Another option may be replacement of the catheter using peritoneal tunneling, but this also needs further study. At the conclusion of any revision procedure, dialysate is infused and drained to ensure adequate inflow and outflow, as well as patency of the catheter [189].

Omental involvement must also be addressed in revision of PD catheters by either omentectomy, omentopexy or omental folding. Selective use of omentectomy has been advocated by several authors [129, 219, 220, 223–226], although omentopexy may be less complicated [226, 227]. This can be accomplished in a variety of ways, depending on the preference of the operating surgeon. Omental folding described by Goh involves folding the omentum cephalad on itself and suturing it to the gastrocolic omentum, effectively shortening its length [131]. This technique was evaluated in a prospective study. Among 18 patients in which omental wrapping was observed to be the etiology for catheter malfunction, two failures were observed. One patient developed recurrent catheter obstruction 2 weeks after surgery requiring HD due to extensive small bowel adhesions and a second patient developed recurrent malfunction 5.5 months later which was successfully salvaged by adhesiolysis at subsequent laparoscopic exploration. Thus, this author reports a success rate of 89 % (16/18) for initial laparoscopic salvage with a mean follow-up of 16.5 months [131]. Obstruction may occur from other intra-abdominal structures including fallopian tubes, epiploic appendages, vermiform appendix, and small bowel. In one large study, the management of such adhesions included salpingectomy, resection of epiploic appendages, appendectomy, and adhesiolysis [110]. With modern use of advanced techniques, the more common reasons for catheter malfunction (i.e. catheter migration, omental adhesions) may become less prevalent. Regardless, laparoscopic exploration allows the surgeon to uncover the reason for catheter malfunction and individualize treatment for each patient. If laparoscopic revision fails or is not available, catheter replacement is an option [8]

PD may be resumed shortly following revision of a malfunctioning PD catheter [228, 229]. Following percutaneous manipulation through the catheter, PD may be resumed immediately. Following laparoscopic surgery, PD may be resumed as early as postoperative day one with the patient in the supine position. Exchange volumes are less than one liter at first and may then be gradually increased over the following week if the patient tolerates the increase [228, 230]. There are no comparative trials regarding this subject, however, Lin suggested a 9 day waiting period to avoid dialysate leak [231].

Outcomes

There are no trials comparing lap to open revision of PD catheters. In addition, open revision is rarely described in the literature. Therefore, evidence to support the techniques discussed above consists mainly of retrospective studies. Yilmazlar et al. retrospectively evaluated 37 patients who underwent laparoscopic revision, in which catheter repositioning and/or adhesiolysis were performed. Catheter patency rates at 30 days and at 12 months were reported as 97.2 and 62 %, respectively. Catheter malfunction recurred in 12 of these patients at a mean of 12.4 months, and 5 of them were successfully managed with an additional laparoscopic salvage procedure [189]. Amerling, et al. reported a series of 26 cases of successful laparoscopic catheter revision; five of these cases involved partial omentectomy. Four patients in this series developed recurrent malfunction; three of these were successfully managed with an additional laparoscopic procedure. These salvaged catheters remained patent for a mean of 9.2 months [219]. A retrospective review of 12 patients undergoing catheter revision using selective omentectomy and catheter fixation reported 100 % catheter function at a median of 21 months [223]. In summary, laparoscopic salvage of malfunctioning PD catheters results in early success rates of 82 to 100 %. However, long-term >30 day success is more variable as two studies showed failure rates of about 60 %. A summary of laparoscopic salvage articles is presented in Table 8.

Limitations of the available literature

The available literature on laparoscopic PD catheter insertion and salvage has several limitations. Most studies are retrospective in nature and many differences in techniques were observed. In trials comparing insertion techniques, there are small numbers and an increased risk for bias and other confounding factors. In addition, the expertise of the operators may vary significantly and for some insertion techniques high-risk patients such as those with history of prior abdominal surgery were excluded. The reporting of outcome measures varies also as some papers split up catheter migration and outflow obstruction as causes for dysfunction. Additionally, protocols vary such as the time period between surgery and the start of PD. This can make a comparison of leak rates inaccurate. Finally, the follow-up periods vary greatly, but generally tended to be short making it difficult to compare data on one technique versus another.

Summary of guideline recommendations

Patient selection

1. Contraindications for laparoscopic PD catheter placement include active abdominal infection and uncorrectable mechanical defects of the abdominal wall (+++Evidence, Strong recommendation)
2. History of prior abdominal surgery, regardless of how many, is not a contraindication to laparoscopic PD catheter insertion. It is appropriate for surgeons with experience in advanced laparoscopy to attempt lysis of adhesions and catheter placement in these patients. (++Evidence, Strong recommendation,)
3. Patients with abdominal wall hernias should be diagnosed and repaired before or at the same time as PD catheter insertion. A repair should be chosen that minimizes peritoneal dissection and does not place mesh intraperitoneally (++Evidence, Weak recommendation)
4. PD may be initiated in patients with intraabdominal foreign bodies such as after open AAA graft repair, but a 4-month waiting period is recommended. Very limited data exist regarding PD in the presence of an adjustable gastric band. (++Evidence, Weak recommendation)
5. PD may be safely initiated in patients with ventriculoperitoneal shunts (++Evidence, Weak recommendation)
6. Gastrostomy tubes can be used in pediatric patients on PD, though placement by blind PEG appears to be associated with higher infection rates compared to open insertion. (++Evidence, Weak recommendation)
7. Laparoscopic PD catheter insertion with carbon dioxide pneumoperitoneum requires general anesthesia. Patients who are high risk to undergo general anesthesia should be considered for a technique of catheter insertion that only requires local anesthesia and sedation, such as open insertion or fluoroscopically guided percutaneous insertion. Laparoscopic insertion using nitrous oxide pneumoperitoneum and local anesthesia is also an option where available. (++Evidence, Weak recommendation)

Insertion options

8. For peritoneal access, blind percutaneous, open surgical, peritoneoscopic, fluoroscopically guided percutaneous, and laparoscopic insertion procedures, when performed by experienced operators, are feasible and safe with acceptable outcomes. (++++, Strong recommendation)

Advanced laparoscopic techniques to avoid catheter dysfunction

9. Laparoscopic lysis of adhesions should be incorporated to reduce catheter dysfunction. (+++Evidence, Strong recommendation)
10. Laparoscopic suture fixation of the PD catheter may reduce catheter dysfunction but additional evidence is needed. (++Evidence, Weak recommendation)
11. Rectus sheath tunneling helps prevent migration and may be superior to suture fixation since it does not require added ports and instruments. (++Evidence, Weak recommendation)
12. Omentopexy in adults is a safe adjunct to laparoscopic PD catheter insertion and should be incorporated either routinely or selectively to reduce catheter dysfunction. (+++Evidence, Weak recommendation)
13. Omentectomy should be considered in pediatric patients undergoing PD catheter placement (++Evidence, Weak recommendation)
14. The combination of lysis of adhesions, rectus sheath tunneling, and omentopexy in combination offers the lowest rate of postoperative PD catheter dysfunction and should be a preferred technique in adults. (+++Evidence, Strong recommendation)

Perioperative considerations

15. Pre-surgical assessment should include thorough examination for hernias and the catheter exit site should be marked before surgery. (+Evidence, Weak recommendation)

Table 8 Summary of papers on laparoscopic salvage of malfunctioning PD catheters

Author	Year	No.	Cause of obstruction					Function		
			Omentum	Adhesions	Migration	Plugging	Other	<30 day	>30	Treatment
Kimmelstiel [218]	1993	8	6	2	0	0	0	NR	75 %	Adhesiolysis, omentectomy, repositioning
Brandt [217]	1996	26	0	19	7	0	0	NR	96 %	Adhesiolysis, repositioning
Amerling [219]	1997	28	0	26	0	0	2 hernias	93 %	38 %	Adhesiolysis, catheter freed
Barone [220]	1998	17	NR	NR	NR	NR	NR	82 %	42 %	Omentectomy, adhesiolysis
Ogunc [226]	2002	8	3	1	3	1	0	100 %	NR	Omentectomy, adhesiolysis, suture fixation, fibrin removal
Ovant [223]	2002	12	0	4	8	0	0	100 %	100 %	Lysis of adhesions & repositioning
Lee [224]	2002	13	12	0	0	0	1	62 %	NR	Omentectomy & suture fixation
Jonler [232]	2003	14	0	13	0	0	1	NR	93 %	Suture fixation of catheter
Yilmazlar [189]	2006	40	0	10	27	0	3 peritonitis	97.2 %	62 % 12 months	Reposition, adhesiolysis, catheter removal for infection
Numanoglu [222]	2007	13	1	4	4	0	4 peritonitis	4 peritonitis	NR	Suture fixation of catheter
Goh [131]	2008	18	18	0	0	0	0	94 %	89 %	Omental folding and sling fixation in all cases
Zoland [233]	2010	4	2	2	0	0	0	NR	100 %	Adhesiolysis
Zakaria [234]	2011	21	15	0	4	0	2	100 %	100 %	Adhesiolysis, repositioning, catheter replacement due to infection

16. A need for pre-operative bowel preparation has not been conclusively demonstrated and further evidence is needed before a recommendation can be provided
17. Prophylactic antibiotics should be used prior to laparoscopic insertion of PD catheter. Vancomycin may be superior to first generation cephalosporins in minimizing early peritonitis after PD insertion. However, its routine use should only be considered based on local resistance patterns and outcomes. (+++Evidence, Strong recommendation)

Surgical technique

18. Peritoneal access during lap PD insertion should be obtained away from previous scars; surgeons should use the technique they are most comfortable and experienced with. (++Evidence, Weak recommendation)
19. The surgeon should minimize the size and number of ports used and place them in a manner that optimizes visualization of the catheter peritoneal insertion point and the pelvis. (++Evidence, Weak recommendation)
20. When inserting the PD catheter through the abdominal wall, the deep cuff should be placed inside the rectus sheath. (++Evidence, Strong recommendation).
21. The superficial PD catheter cuff should be 2 cm from the skin exit site in children and at least 2 cm in adults to prevent future cuff extrusion. (+Evidence, Weak recommendation) (++Evidence, Weak recommendation)

Postoperative protocol

22. Minimizing dressing changes and handling may be beneficial in the first two postop weeks. (+Evidence, Weak recommendation)
23. Adequate time should be given after surgery for healing before PD is initiated and the current standard is two weeks. A more urgent start should be considered when the benefits outweigh the risks (++Evidence, Weak recommendation)

Outcomes by surgical procedure

24. Blind percutaneous PD catheter insertion has acceptable malfunction and leak rates compared with open insertion in patients who have never had prior abdominal surgery. The technique may be especially useful in high-risk patients for general anesthesia as it can be performed at the bedside, under local anesthesia by trained nephrologists. However, bowel perforation and bleeding risk should be considered (+++Evidence, Weak recommendation)
25. Open surgical insertion continues to be a standard to which others are compared. It is safe (low perforation rate) and effective and can be performed under local anesthesia and sedation. It appears to have higher leak and dysfunction rates compared to image-guided percutaneous and advanced laparoscopic insertion. (+++Evidence, Weak recommendation)
26. Peritoneoscopic insertion is a technique used worldwide, mostly by "interventional" nephrologists. It has been studied in patients who have had prior surgery, but there is at least a 1 % perforation rate. It appears to be comparable to open surgical insertion in experienced hands, but has not been compared to laparoscopic- and fluoroscopic-guided percutaneous insertion. (++Evidence, Weak recommendation)
27. In patients without prior abdominal surgery, percutaneous fluoroscopic PD catheter insertion results in similar or better complication rates and dysfunction rates compared to open or basic laparoscopic insertion, and avoids general anesthesia. (+++Evidence, Weak recommendation)
28. Basic laparoscopic insertion without using techniques to minimize catheter dysfunction results in similar dysfunction rates as open insertion. (+++Evidence, Strong recommendation)
29. Advanced laparoscopic PD catheter insertion using lysis of adhesions, catheter fixation preferably with rectus sheath tunnel, and omentopexy performed in combination has the lowest reported rate of catheter dysfunction in adults, even in patients with prior abdominal surgery. (+++Evidence, Strong recommendation)

Early postop complications

30. Bleeding after PD catheter insertion may occur from inferior epigastric artery injury or lysis of adhesions and should be managed according to standard surgical principals. The insertion point should be at the medial border of the rectus sheath to avoid arterial injury. Coagulation parameters should be assessed and corrected pre-operatively. (+Evidence, Weak recommendation)
31. Dialysate leaks after PD catheter placement may be amenable to treatment, and potentially prevention, with the use of fibrin glue, particularly in the pediatric population. (++Evidence, Weak recommendation.)
32. Exit site infection is managed by oral antibiotics. Chronic exit site and cuff infections may managed by catheter salvage consisting of unroofing the track,

shaving the superficial cuff, and using a new exit site. (++Evidence, Weak recommendation)

33. Pain during PD is a rare complication that is usually amenable to medical management but occasionally requires repositioning or removal of the catheter. (++Evidence, Weak recommendation)

Pd catheter malfunction

34. Malfunctioning PD catheters should be evaluated by physical examination and plain radiographs to rule out constipation. If negative, further studies such as catheterography or CT peritoneography, followed by diagnostic laparoscopy are indicated. (++Evidence, Weak recommendation)
35. Non-operative treatments of malfunctioning PD catheters which have been proven effective include flushing, thrombolytics and fluoroscopic wire manipulation. (++Evidence, Weak recommendation)
36. Patients with malfunctioning PD catheters not amenable to non-operative measures should undergo laparoscopy with catheter repositioning, adhesiolysis, omentectomy, or omentopexy. Patency should be assured by stripping and flushing. Suture fixation of the catheter to the pelvis or polypropylene sling may be utilized to reduce catheter migration. Surgical techniques for catheter salvage require individualization based upon operative findings. (+++Evidence, Strong recommendation)

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