12 Peritoneal Access in Children Receiving Dialysis

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Peritoneal Dialysis Access

Peritoneal dialysis (PD) is the initial dialytic modality for many children with end-stage kidney disease (ESKD). This is especially true for children who have acquired ESKD during their first decade of life [1]. Data from the North American Pediatric Renal Trials and Collaborative Studies (NAPRTCS) reveals that of the 9108 courses of dialysis recorded in the dialysis registry between 1992 and 2010, 58% were for PD [2]. The 2018 report of the United States Renal Data System (USRDS) also revealed that PD was the most common initial ESKD treatment modality for children aged 9 years and younger and that 86.1% of those patients <10 kg at dialysis initiation were prescribed PD (Fig. 12.1) [1]. Reasons for the preferential selection of PD in children have included its ability to greatly reduce the need for dietary restrictions, its simplicity of operation, the lack of a need for routine blood access, and the ability of the child on PD to attend school on a regular basis.

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In order for there to be successful PD, there must be a well-functioning peritoneal catheter. Ideally, the catheter provides reliable, rapid dialysate flow rates without leaks or infections. The first description of placement of a chronic indwelling catheter for peritoneal dialysis was in 1968 by Tenckhoff, and the Tenckhoff catheter continues to be the most commonly used PD access [3, 4]. Despite significant improvements in catheter design, however, the catheter has continued to be the Achilles' heel of PD because of catheter-related complications. This chapter will explore the key characteristics of the catheters, the primary surgical techniques for their placement, as well as the most common catheter-related complications in children. It is hoped that this information will result in an increased likelihood of a problem-free PD access for the pediatric patient.

Access Types

The catheters that are commonly used for chronic PD are constructed of soft material, such as silicone rubber or polyurethane. The key elements of the catheters are the unique intraperitoneal configurations (curled or straight), number of Dacron cuffs (one or two), and the subcutaneous tunnel configuration (straight or "swan neck") [5, 6]. If one includes the orientation of the catheter exit site on the abdomen as yet another variable, more than 20 different combinations of catheter characteristics are possible, as documented in the

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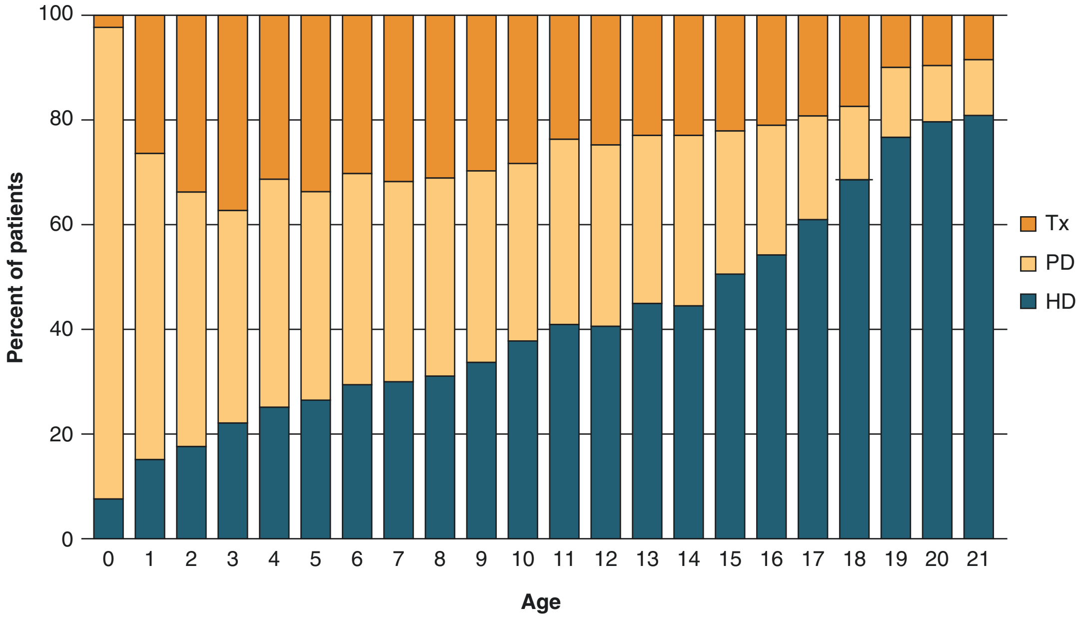

Fig. 12.1 Cross-sectionaltrends in pediatric ESKD modality at initiation by patient age 1996–2016. (Modified from Ref. [1])

Table 12.1 Peritoneal dialysis access characteristics

Catheter	Cuffs	Tunnel	Exit site	N (4391)[a]	% (100.0)
Curled	One	Straight	Lateral	619	14.1
Curled	Two	Swan necked/curved	Down	458	10.4
Curled	Two	Straight	Lateral	315	7.2
Straight	One	Straight	Lateral	313	7.1
Curled	Two	Straight	Down	277	6.3
Curled	One	Straight	Down	267	6.1
Curled	One	Straight	Up	209	4.8
Straight	One	Straight	Up	136	3.1
Presternal	Two	Swan necked/curved	Down	129	2.9
Straight	One	Straight	Unknown	123	2.8
Curled	Two	Swan necked/curved	Lateral	132	3.0
Curled	Two	Swan necked/curved	Unknown	145	3.3
Straight	One	Swan necked/curved	Lateral	104	2.4
Straight	Two	Straight	Lateral	100	2.3
Straight	One	Straight	Down	102	2.3
Curled	One	Straight	Unknown	76	1.7
Curled	One	Swan necked/curved	Down	78	1.8
Curled	One	Swan necked/curved	Lateral	78	1.8
Curled	Two	Straight	Unknown	57	1.3
Straight	Two	Straight	Up	54	1.2
All other combination (<1% each)				618	14.1

[a]Cases with missing elements are excluded

2011 annual report of the NAPRTCS (Table 12.1) [2]. As noted above, the most common catheter with these characteristics used by pediatric patients is the Tenckhoff catheter.

A review of the 2011 NAPRTCS dialysis registry catheter data reveals that most of the catheters that were placed were of the Tenckhoff curled (62.1%) or Tenckhoff straight (25.9%) variety [2]

Table 12.2 Peritoneal dialysis access

	N	%
Peritoneal dialysis courses	4687	100.0
Catheter		
Tenckhoff straight	1213	25.9
Tenckhoff curled	2909	62.1
Toronto Western	26	0.6
Presternal	272	5.8
Other	111	2.4
Unknown/missing	156	3.3
Cuffs		
One	2375	50.7
Two	2124	45.3
Unknown/missing	188	4.0
Tunnel		
Swan neck/curved	1590	33.9
Straight	2895	61.8
Unknown/missing	202	4.3
Exit-site orientation		
Up	564	12.0
Down	1537	32.8
Lateral	1816	38.7
Unknown/missing	770	16.4

(Table 12.2). More recently, the Standardizing Care to Improve Outcomes in Pediatric ESRD (SCOPE) Collaborative showed that of 857 PD catheters, 94.1% were Tenckhoff curled catheters and 5.9% were Tenckhoff straight catheters [7]. The presumed advantages of the curled catheter over the original straight catheter include (1) better separation between the abdominal wall and the bowel, (2) more catheter side holes available for inflow and outflow, (3) less inflow pain, (4) less of a tendency for migration out of the pelvis, (5) less prone to omental wrapping, and (6) potentially less trauma to bowel [8]. However, in contrast to the North American data, the Italian PD registry reflects a predominance of straight catheters, and the adult experience has not revealed any clear difference in functionality [9]. In fact, it should be emphasized that none of the eight adult randomized trials reviewed in the 2017 ISPD Catheter-Related Infection Recommendations which compared straight and coiled PD catheters found differences in the rates of catheter-related infections [10–12]. In addition, two recent studies conducted in adult PD patients revealed a superior outcome with the straight Tenckhoff catheter in terms of catheter survival, whereas in a large pediatric study, use of a swan neck catheter with a curled intraperitoneal segment was a significant risk factor for access revision [12–14]. Finally, neither the NAPRTCS nor the SCOPE data has provided evidence for any association between the intraperitoneal catheter configuration and the development of peritonitis or exit-site/tunnel infection [2, 7].

The next catheter characteristic to consider is the number of Dacron cuffs on the catheter. If a single-cuff catheter is used, it is generally recommended that the cuff be positioned between the rectus sheaths in the rectus muscle, and not in a superficial position. In one series, the incidence of peritonitis was decreased by nearly 37% when the cuff was placed in the rectus sheath compared to a subcutaneous placement of the cuff. When a second cuff was added as a means of securing the catheter's position and potentially helping prevent bacterial migration, there were initial reports of problems with cutaneous extrusion of the second cuff [15, 16]. This was most likely secondary to excess torque being placed on the catheter at the time of placement as a result of the angle between the exit-site and the abdominal wall portion of the catheter. It also proved most likely to occur if the outer cuff was less than 2.0 cm from the exit site, an exceedingly important factor to recognize when placing double-cuff catheters [5, 8]. Cuff extrusion may lead to the cuff being seeded with bacteria and may predispose to the development of an exit-site/tunnel infection. A cuff that has completely extruded still remains a risk factor for an exit-site infection. Thus, cuff extrusion should prompt shaving of the cuff off the catheter [17–19]. While there are very few reports describing the incidence of distal cuff extrusion with double-cuff catheters in children, three series have reported outer cuff extrusion rates of 5.7%, 8%, and 4.8%, respectively [9, 20, 21]. It may be, in part, for this reason that 51% of the catheters in the NAPRTCS database are single cuff [2]. There is, however, some data to suggest that single-cuff catheters are associated with a higher incidence of exit-site/tunnel infections and peritonitis. Lewis et al. compared the incidence of catheter-related infections in children with single- and double-cuff peritoneal catheters and found a significantly lower incidence of infections in the double-cuff group [22]. A similar conclusion can be drawn from the NAPRTCS 2011 registry data that revealed a significantly lower incidence of peritonitis in association with double-cuff catheters (1/21.6 patient-months) compared to single-cuff catheters (1/16.2 patient-months), although the experience varies in individual centers [2, 21, 23]. In addition, the NAPRTCS data shows a longer time to first peritonitis episode in the double-cuff catheter group [2] . However, the SCOPE Collaborative has failed to show any relationship between the number of catheter cuffs and the development of an exit-site/tunnel infection, and several prospective studies in adults and one quality improvement initiative in children have failed to show a difference in peritonitis rates for single- and double-cuff catheters [5, 7]. Of particular interest, a large retrospective cohort study in adults subsequently suggested that the effect of the number of cuffs may be era related, with the benefit of two cuffs negated by the use of prophylactic antibiotics at the catheter exit site [24]. In turn, despite conflicting data and, most importantly, the lack of the necessary randomized controlled trials, the ISPD has suggested that the use of two cuffs may still be preferable because of non-compliance with the routine application of antibiotics at the catheter exit site [5]. Perhaps in response to this type of data, the NAPRTCS database shows that 52% of catheters in 2002–2011 had two cuffs and, more recently, 73% of the catheters in SCOPE centers had two cuffs [7, 25].

The shape of the extraperitoneal portion of the catheter is variable and can be straight or can have a preformed angle (e.g., "swan neck" configuration), in which there is an inverted U-shaped arc (170–180°) between the deep and the superficial cuffs (Fig. 12.2). The latter configuration was originally described by Twardowski et al. and has been recommended by many pediatric programs as a significant improvement in catheter design [26, 27]. While the cumulative NAPRTCS data reports a swan neck/curved tunnel in only 33.9% of catheters (identical to the results of the North American survey by Washburn et al.), the percentage of catheters in the NAPRTCS data that had the swan neck design increased from 24.7% in 1992–2001 to 53.1% in data collected from 2001–2011 [25, 28]. Likewise, the SCOPE Collaborative and the IPPN reported that 68.6% and 74% of their catheters, respectively, had a swan neck tunnel configuration [7, 29]. The purpose of the catheter arc is to (1) allow the catheter to exit the skin in a downward pointing direction and to (2) allow the distal end of the catheter to enter the peritoneal cavity in an unstressed condition (i.e., without too much torque because of the synthetic material's memory), thereby decreasing the chance for its migration out of the pelvis and the development of early drainage failure. Most studies have found this positive outcome to be true [30–32].

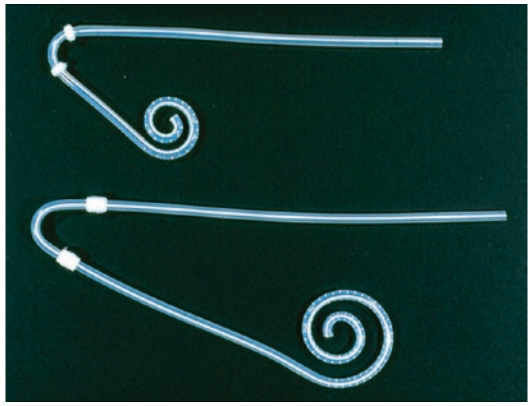

Fig. 12.2 Picture of a Tenckhoff, double-cuff curled catheter with swan neck bend

A modification of this catheter type is the swan neck presternal catheter. The major difference between the swan neck presternal catheter and the standard swan neck catheter is that the presternal catheter has a very long subcutaneous portion and the catheter typically exits over the anterior chest wall. This catheter has been utilized when it is necessary to make the exit site remote from the abdomen, such as in obese patients or patients with incontinence, intestinal stomas, and suprapubic catheters. Crabtree et al. have reported their experience with remote exit sites in adults [33]. They noted a significantly longer time to first exit-site/tunnel infection in the remote exit-site group compared to a standard exit-site group. However, they also noted a higher incidence of catheter loss from peritonitis in the remote exit-site group. They attributed this to an increased incidence of both an elevated BMI and diabetes in the remote exit-site group. Warchol et al. documented an exit-site infection rate of 1/70.2 patient-months in association with presternal catheter usage in the largest pediatric experience [34]. In a similar manner, locating the catheter exit site on the chest wall of infants with a colostomy has been associated with an acceptable risk of contamination and infrequent peritonitis [35]. However, infants with complex congenital anomalies that require intestinal stomas and a PD catheter exit site that is remote from the stomas often have minimal subcutaneous tissue over the chest which makes cuff erosion/extrusion more likely in that location. One suggested approach to this problem would be to place the two cuffs below the costal margin and then have the catheter exit high on the chest wall [36]. Conversely, a single-cuff catheter may be most desirable.

As mentioned above, a presumed advantage of the swan neck catheter is that it allows a downward pointing exit site which may be associated with a decreased likelihood for the accumulation of dirt and debris within the catheter tunnel prompting the development of a tunnel infection/peritonitis. An upward facing exit site emerged as an independent risk factor for peritonitis in an analysis by Furth et al. of the 1992–1997 NAPRTCS data [37]. The 2011 NAPRTCS data revealed that a straight catheter tunnel was associated with a peritonitis rate of 1/16.2 patient-months, while the rate associated with a swan neck/curved tunnel was only 1/23.9 patient-months [2]. Likewise, the peritonitis rates associated with an upward- and downward-oriented exit site were 1/14.5 patient-months and 1/22.6 patient-months, respectively [2]. In the recent SCOPE analysis of risk factors for peritonitis, the multivariate analysis also revealed that an upward orientation of the exit site was an independent risk factor for peritonitis (RR, 4.2; 95% CI, 1.49 to 11.89; $P < 0.01$) [7]. Finally, while some studies have found the use of the swan neck catheter to be associated with less frequent cuff extrusion, exit-site irritation, and exit-site/tunnel infections, other studies have been unable to confirm the results [38, 39]. In addition, and as mentioned previously, data from the IPPN revealed that the presence of a swan neck tunnel was a significant risk factor for access revision (OR, 1.30; 95% CI, 1.04 to 1.63; $P = 0.02$) [14].

An alternative to the swan neck catheter has been reported by several authors from China [40–42]. They compared the efficacy of using a preformed swan neck catheter to a straight Tenckhoff catheter that was bent into a swan neck configuration (using three surgical incisions) to permit a downward-facing exit site. In all three studies, the performance of the operatively bent Tenckhoff catheter was comparable to the swan neck catheter. The benefit of the latter catheter is related to its significantly lower cost than the swan neck catheter in China.

In summary, the lack of prospective studies in pediatrics designed to evaluate PD catheter characteristics makes it impossible to conclude that one catheter characteristic is superior to another based upon definitive evidence. The NAPRTCS registry data is quite convincing and points out that the time to first peritonitis episode is longer with catheters characterized by two cuffs compared to one, swan neck tunnels compared to straight tunnels, and downward exit sites compared to lateral and upward exit sites. The benefit of this combination of characteristics on decreasing the incidence of peritonitis is significant (Fig. 12.3) [2]. Nevertheless, both the pediatric and adult data highlight the need for additional information on this important topic. Thus, the continued collection of catheter-related data in registries such as the NAPRTCS, SCOPE, and the IPPN, along with the performance of prospective trials, is mandatory if the optimal catheter characteristics are to be determined.

Preoperative Evaluation and Preparation

All patients who are going to undergo PD catheter placement require careful preoperative evaluation. One factor that has been repeatedly cited in

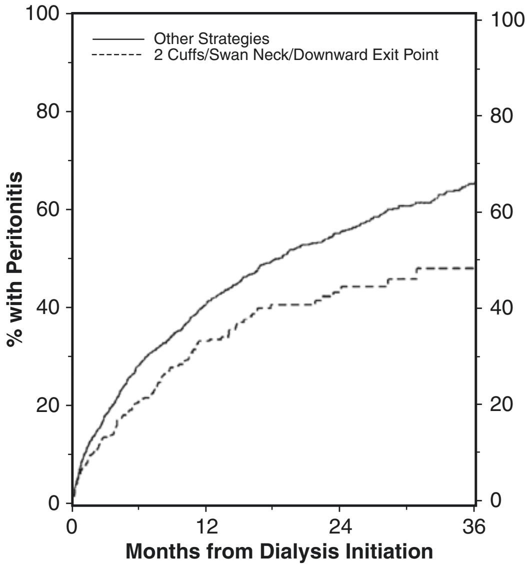

Fig. 12.3 Comparison between catheter with downward-facing exit site, swan neck, and two cuffs versus all other strategies and the time to first episode of peritonitis. (Source: Adapted from Ref. [2])

the literature as being associated with an increased risk for post-placement PD catheter migration is constipation [43]. Constipation is common in patients with chronic kidney disease (CKD) and must be addressed preoperatively with the use of either laxatives or an enema. If an enema is used, attention to its phosphorus content is imperative.

A careful preoperative physical examination is required to determine if the patient has any evidence of a hernia. In children who receive PD, the incidence of hernias is inversely proportional to age, with an overall frequency of 8.0–57.0% [44–47]. The highest frequency of inguinal hernias occurs within the first year of life; they are often bilateral and all require surgical correction. Umbilical hernias can worsen in the PD patient as a result of the increase in intra-abdominal pressure generated by the dialysis fluid. As a result, some have advocated peritoneography or laparoscopic inspection for hernias at the time of catheter placement [45]. If detected, the hernias can then be fixed at the same time the PD catheter is inserted [48–50]. Forehand knowledge of the need for hernia repair will allow the surgeon to allot the appropriate operative time to perform this additional procedure.

A critical portion of the catheter placement procedure is deciding upon the most appropriate location of the exit site. In babies, the exit site of the catheter needs to be outside of the diaper area to help prevent contamination. In older children, it should be either above or below the beltline. The location of the exit site should be discussed with the patient and parents in the preoperative setting. The presence of a vesicostomy, ureterostomy, colostomy, or gastrostomy will also influence the exit-site location. As noted previously, the exit site must be planned so that it is either on the opposite side of the abdomen from any stoma site or, if this is not possible, the catheter may need to exit on the chest in order to increase the distance between the stoma and the exit site. Placement of the exit site on the chest wall with a downward orientation has successfully limited the number of infections in such high-risk situations in children and adults [5, 34, 35, 50, 51]. As younger and generally more complex babies are now surviving, the need for peritoneal dialysis in the setting of multiple stomas is becoming much more common and mandates particular attention to this catheter-related issue [36].

Preoperative showering and the use of chlorhexidine wipes for several days prior to the operative procedure may help decrease the risk of postoperative infection [52]. Preoperative antibiotic administration within 60 minutes prior to PD catheter placement has also been shown, in several studies, to decrease the incidence of peritonitis after insertion of a PD catheter in both children and adults [10, 11, 53, 54]. Interestingly, these studies have shown that any class of antibiotic will be beneficial [5, 10, 53, 55, 56]. Currently, we utilize a first- or second-generation cephalosporin to provide antistaphylococcal coverage, unless the patient is known to already be colonized with *methicillin-resistant Staphylococcus aureus* (MRSA). In the presence of MRSA, we recommend the prophylactic use of clindamycin. This recommendation comes from the pediatric and adult guidelines of the International Society for Peritoneal Dialysis (ISPD) [10, 53, 57].

Routine prophylaxis with vancomycin is not recommended in order to try to avoid the development of vancomycin-resistant organisms, despite the finding in an adult experience of superior results with prophylactic vancomycin versus a cephalosporin [57]. If the child has a lower gastrointestinal stoma, we often add a single dose of an aminoglycoside antibiotic.

Some programs, including our own, will also screen the patient for *S. aureus* nasal carriage prior to PD catheter placement. If positive, a course of intranasal mupirocin (twice daily for 5 days) is recommended [58]. This approach has also recently been recommended by the ISPD [10].

Omentectomy

The data recommending the performance of an omentectomy/omentopexy at the time of catheter placement to prevent PD catheter occlusion is compelling [59]. If an omentectomy is performed, the incidence of catheter occlusion is about 5% compared to an occlusion rate of 10–22.7% in patients without an omentectomy [49, 60]. A survey conducted by the Pediatric Peritoneal Dialysis Study Consortium (PPDSC) found that an omentectomy was routinely performed in 53% of pediatric centers at the time of catheter placement, similar to the 59% figure derived from a survey of North American surgeons [28, 61]. An omentectomy was performed with the insertion of 82.4% of catheters in the Italian PD registry [4]. In a single-center study of 101 pediatric PD patients who underwent reoperation for infection or catheter malfunction, the lack of an omentectomy was a significant risk factor for catheter revision [62]. In practical terms, the omentectomy does not have to be complete. The remnant amount needs to be such that it cannot reach to the catheter once the catheter is positioned in the pelvis.

One group of investigators, however, interpreted their own data related to the issue of omentectomy somewhat differently [60]. Even though they noted a 20% decrease in the incidence of catheter blockage with omentectomy, they calculated that 11 omentectomies would be required to prevent two omental PD catheter blockages. Therefore, they felt that nine patients would undergo an unnecessary omentectomy. In their hands, a secondary omentectomy was not difficult, resulting in their conclusion that omentectomies should only be carried out after a blockage occurs.

An omentopexy can be considered as an alternative to omentectomy [63]. Whereas the objection to omentectomy is the potential for bleeding and the obvious need to extract the omentum from the abdomen, an omentopexy decreases the chances of either of these complications and accomplishes the same desired outcome.

In our center, we believe that either an omentectomy or, more recently, an omentopexy is a fairly simple procedure that can be carried out at the initial operation with little morbidity and should be strongly considered in all cases.

Fibrin Sealant

Fibrin glue has been used in a variety of surgical specialties for its ability to be an effective sealant. The use of fibrin glue in PD has been reported to be both effective in treating established leaks and, when used at the time of catheter implantation, may help prevent the development of peritoneal leaks around catheters that are used soon after being placed [64–66]. Our experience with fibrin glue would support both of these assertions. Typically, 5 cc fibrin glue is applied around the internal cuff and down the tunnel between the inner and outer cuffs prior to closing of the catheter insertion incision.

Surgical Technique

Since Moncrief and Popovich first reported on the use of continuous ambulatory peritoneal dialysis (CAPD), there have been a number of modifications of the technique for implantation of the PD catheter [28, 67, 68]. The complications of dialysate leakage, dislocation of the catheter, erosion/extrusion of the cuffs, exit-site/tunnel infections, and peritonitis have in one way or another influenced the surgical technique. The two most common PD catheter insertion techniques are the open and laparoscopic techniques. Other approaches include blind placement using the Tenckhoff trocar, blind placement using a guide wire (Seldinger technique), and the mini-trocar peritoneoscopy placement technique [5].

To date, there is no conclusive evidence to suggest that a laparoscopic approach is superior to the open approach [69]. However, over the last few years, several authors have reviewed their experience and concluded that a laparoscopic approach does offer some advantages over the open approach [70–72]. Crabtree et al. have reported a 96% 5-year primary catheter survival without revision and a 99% assisted 5-year catheter survival using a laparoscopic approach [5]. In a prior review of the literature, there was evidence presented on the incidence of PD catheter flow dysfunction and its relationship to the insertion technique: percutaneous needle/guide wire, 10.5–11.2%; open surgical placement, 10.4–17.1%; and laparoscopic, 6–6.9% [70]. The low incidence of catheter flow problems in the laparoscopic group was attributed to a combination of rectus sheath tunneling of the catheter (allowing for positioning of the catheter in the pelvis), along with managing the omentum with either omentopexy or omentectomy. Crabtree et al. have also found that the laparoscopic approach was not necessarily contraindicated when there has been previous surgery or peritonitis [73]. Another author codified their laparoscopic approach as the three-in-one procedure (PD catheter placement, omentectomy, and repair of any hernias). In their series, they described a statistically significant longer catheter life, decreased need for reoperations, and no incidence of omental blockage [74]. At our institution, we currently use the laparoscopic technique as our preferred method for catheter insertion.

Laparoscopic Technique

With the use of laparoscopy, placement of a PD catheter can be performed under direct vision [75]. Additional advantages of the laparoscopic technique are that it allows the use of much smaller peritoneal incisions, thereby decreasing the chance for dialysate leakage, and it makes it possible to conduct a thorough examination of the abdomen. If any pathology is identified that would potentially interfere with catheter performance (adhesions, inguinal hernias), the problem(s) can be corrected at the time of catheter placement. We currently use a modification of the technique first described by Daschner et al. [76] and more recently by Crabtree et al. [70].

The catheter insertion site is chosen with consideration of the patient's size, the need for the catheter to exit in a downward direction, and the presence of any stomas. Consideration must also be given to the fact that small children may need a gastrostomy in the future. If there are no plans for a gastrostomy at the time of PD catheter placement or later, we prefer to place the catheter on the left side of the abdomen so that it is away from the future transplant incision. The exit site of the catheter in our hands is typically positioned above the beltline or diaper area. However, in very large children, it may be necessary to locate the catheter below the beltline so that the catheter will reach into the pelvis. The catheter entrance site is marked, usually just lateral and below the umbilicus, over the rectus sheath. An appropriate-sized catheter is then picked by having the inner cuff of the catheter over the entrance site and the bottom of the curl at the symphysis pubis. The exit site is then located and marked so that the catheter's exit site orientation will be downgoing.

Under general anesthesia, a vertical incision is made in the umbilicus, and the umbilical fascia is sharply incised. Using blunt dissection, the peritoneum is entered and a 5 mm port is placed. A 5 mm laparoscope is then inserted and the abdomen is insufflated. A 3 mm instrument is then inserted through a stab wound at the marked catheter exit site. The abdomen is then inspected for any adhesions or inguinal hernias. If adhesions are noted, they are lysed at this time, and any inguinal hernias are repaired laparoscopically at the end of the case. The omentum is then assessed and, if necessary, removed. We feel that a complete omentectomy is not necessary as long as the omentum is prevented from entering the pelvis. We remove the omentum by inserting a 3 mm scope via the 3 mm stab wound, and the omentum is pulled out via the umbilicus and excised with electrocautery. The omentum can also be plicated using different techniques [5].

A 2 cm transverse incision is then made at the previously marked entrance site for the PD catheter and carried down to the anterior rectus sheath. The anterior sheath is opened for a distance of 3 mm, and a 5 mm port is inserted through the rectus muscle down to the posterior rectus sheath and then tunneled under direct vision via the umbilical camera for a distance of between 3 and 7 cm (depending on the size of the patient), and then the tip of the port is popped into the abdomen above the bladder.

A guide wire is inserted into the abdomen via the entrance site port. The port is then removed and a 20 French sheath is inserted into the abdomen over the guide wire (Fig. 12.4). The PD catheter is then inserted deep into the pelvis behind the bladder (uterus) under direct vision. The pneumoperitoneum is maintained by pushing the proximal cuff of the PD catheter into the sheath and clamping the end of catheter, thereby preventing gas loss. Once the catheter has been positioned into the pelvis, the sheath is removed (Fig. 12.5). As the sheath is being removed, the inner cuff is positioned to lie between the anterior and posterior portions of the rectus sheath. The inner cuff is then fixed to the anterior rectus sheath with a purse string suture of 3-0 PDS. A second purse string suture of 3-0 PDS is then placed around the fascial exit site of the catheter. Care is taken to make sure that the innermost portion of the cuff does not project into the peritoneum (Fig. 12.6). The camera and all ports are then removed, and the umbilicus is repaired, including repair of any umbilical hernia.

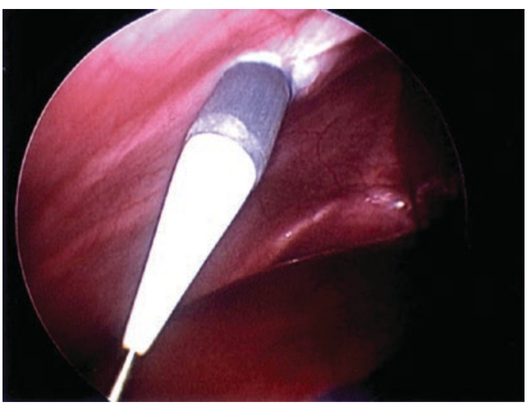

Fig. 12.4 A laparoscopic view of the 20 French peelaway sheath being inserted into the peritoneum over a guide wire. (From Chapter 45, Surgical Issues in Pediatric Peritoneal Dialysis, by Walter S. Andrews. In: Clinical Dialysis, 4th Edition, Nissenson AR, Fine RN, eds. McGraw-Hill Companies, Inc., 2005)

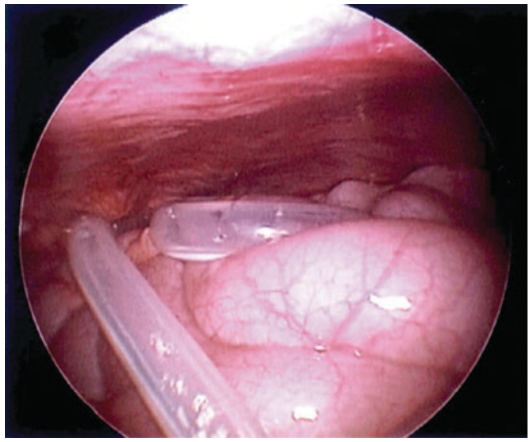

Fig. 12.5 A laparoscopic view of the PD catheter which lies positioned in the pelvis. The catheter is sitting between the bowel and the anterior abdominal wall. (From Chapter 45, Surgical Issues in Pediatric Peritoneal Dialysis, by Walter S. Andrews. In: Clinical Dialysis, 4th Edition, Nissenson AR, Fine RN, eds. McGraw-Hill Companies, Inc., 2005)

At the previously marked catheter exit site, a deep subcutaneous tunnel is created between the catheter exit site and the catheter entrance site using either the previous 20 French sheath dilator or a tendon passer. The end of the catheter is then pulled through the tunnel, positioning the outer cuff so that it is approximately 2.0 cm from the exit site and the end of the catheter is exiting the skin in a downward fashion. Shorter distances between the exit site and outer cuff pre-

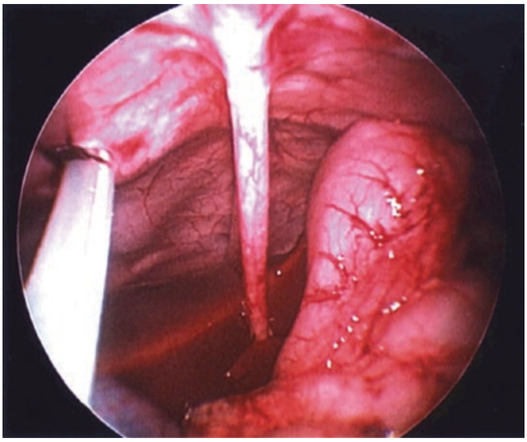

Fig. 12.6 A laparoscopic view of the PD catheter (*left*) showing it leaving the peritoneal cavity. Note that the inner cuff is not visible within the peritoneal cavity. (From Chapter 45, Surgical Issues in Pediatric Peritoneal Dialysis, by Walter S. Andrews. In: Clinical Dialysis, 4th Edition, Nissenson AR, Fine RN, eds. McGraw-Hill Companies, Inc., 2005)

dispose to cuff extrusion, while greater distances lead to formation of a deep sinus tract, granulation tissue formation, and an increased risk of a tunnel infection [48]. At this point, fibrin sealant is injected around the catheter entrance site and down the subcutaneous tunnel and around the second cuff. We feel that this helps insure a leak-free closure. The entrance site of the catheter is then closed in two layers. The exit site of the catheter is dressed, and the catheter is secured to prevent local trauma, but no fixation suture is used at the exit site. The use of a fixation suture is contraindicated because it can contribute to both an exit-site/tunnel infection and poor exit-site healing [5, 53].

Open Technique

Catheter location and length are determined using the same methods as noted with the laparoscopic approach. The most frequent open technique utilizes a transverse incision over the mid portion of the rectus muscle lateral to the umbilicus. The rectus muscle is split in the direction of its fibers and the posterior sheath is then opened longitudinally. An omentectomy is then carried out under direct vision. The PD catheter is threaded over a stiffening wire to allow its placement deep in the pelvis, a few degrees off the midline to help prevent obstruction to flow in the setting of a full rectum. The posterior sheath is closed and the inner cuff is fixed to the posterior sheath as part of this closure. The inner cuff is positioned within the rectus muscle, and the anterior sheath is then closed tightly around the catheter with a second purse string suture around the cuff of the catheter at the level that it exits the anterior rectus sheath. The catheter is then tunneled out to the skin, and the outer cuff is situated 2.0 cm from the catheter exit site, as described above. Fibrin glue is also applied using the same technique as with the laparoscopic approach. An insertion through the rectus sheath is generally deemed preferable to the midline because of the thinness of the abdominal wall in children and a decreased propensity for postoperative leakage [48]. However, the few prospective trials on incision location that have been conducted in adults have not demonstrated a superiority of the rectus sheath versus the midline approach [5].

One advantage of the open technique is the ability to directly visualize placement of the catheter into the pelvis. This can be beneficial in those patients who have previously undergone pelvic surgery. In addition, the open technique allows for an omentectomy to be easily performed at the same time the PD catheter is placed. The major problem with this technique is the necessity for a significant incision in the peritoneum. In turn, for optimal dialysis performance and a decreased likelihood of postoperative leakage of dialysis fluid, this technique ideally requires a 2-week rest period between the time of catheter insertion and the initiation of dialysis [5, 58, 77]. This delay allows for healing of the peritoneal incision and for incorporation of the cuff into the peritoneum and posterior sheath.

Postimplantation Care

The exit site of the catheter, since it is not occlusive, is a potential site of infection after PD catheter placement. In an attempt to address this issue, Moncrief previously suggested that the external portion of the catheter should initially remain buried beneath the skin in a subcutaneous pocket for 4–6 weeks in order for both cuffs to become incorporated into the tissues [78]. After this time period, an exit site is created over the subcutaneous pocket, and the catheter is exteriorized. The patient is able to proceed to full-volume PD without the need for a break-in period. While successful in its application as evidenced by an approximate 90% immediate function rate after externalization, prospective trials comparing initial exteriorization of the catheter versus implantation and subcutaneous burying of the catheter for 6 weeks did not demonstrate a significant difference in the rate of either peritonitis or exit-site/tunnel infections or on long-term catheter survival [5, 8, 79–83]. Twardowski et al., on the other hand, merely recommended that initially, the exit site should only be covered with several layers of sterile gauze and should be kept dry [84, 85]. Some oozing from the exit site is common and the gauze can wick this away from the skin.

An occlusive dressing should *not* be used. Occlusive dressings tend to trap fluid at the exit site predisposing to bacterial growth and subsequent infection. Trauma to the exit site, usually from repeated catheter motion, needs to be minimized. Therefore, the catheter must be securely fixed with a dressing, and dressing changes should not routinely occur more often than once per week until the exit site is healed. Ideally, specially trained staff should conduct the dressing changes, which allows a consistent aseptic technique to be followed and which decreases the risk for bacterial colonization [53, 86, 87]. Submersion of the exit site should be avoided to prevent colonization with waterborne organisms. This is the approach used in our program, one that has helped prevent the development of early exit-site/tunnel infections as a complication of catheter implantation in virtually all cases [86].

Timing of Catheter Use

Some controversy exists as to whether the catheter should be used immediately after placement or whether a timed period (e.g., rest period) should elapse prior to its use to facilitate healing and help prevent the development of complications such as leakage and infection. The 1998 ISPD catheter guidelines recommended a dialysis-free period of 10–15 days after catheter insertion, while the 2005 European guidelines recommended at least a 2-week waiting period, whenever possible [8, 58]. These recommendations were supported by a study conducted by Patel et al. in which immediate versus delayed (an average of 20 days) catheter use was compared [88]. The authors noted an increased incidence of dialysate leakage in the immediate use group, but a disconcerting increase in exit-site/tunnel infections and peritonitis in the delayed catheter use group. In a retrospective review of NAPRTCS data, Rahim et al. found that early (<14 days) versus late onset of usage was associated with an increased risk of leakage, but there was no difference in the risk of infection [77]. The Italian PD registry did not reveal any difference in the incidence of leakage or catheter survival when comparing catheters used early (<7 days) versus late [4]. Most recently, Crabtree et al. recommended a break-in period of at least 2 weeks to decrease the risk of mechanical complications, and Keswani et al. and the SCOPE Collaborative found that dialysis initiation at less than 14 days following PD catheter insertion was significantly associated with the development of peritonitis within 60 days of PD catheter placement [5, 89]. Accordingly, while there is little evidence upon which to generate a definitive recommendation, observational data and expert opinion suggest that delayed PD initiation should be encouraged whenever possible. Of course, when early usage is necessary, efforts should be made to minimize any increase in intraperitoneal pressure by using small exchange volumes, possibly in the supine position with a cycling device [90, 91]. In addition, Imani et al. noted that the risk of postimplantation leaks in infants was greatest in the first 3 days, suggesting that if it was not possible to wait a full 2 weeks to use a catheter, a delay of at least 3 days should be targeted [50].

In contrast to regular PD initiation, many centers do initiate a PD catheter flushing procedure following catheter placement until regular PD is being conducted. The primary reason for flushing is to prevent fibrin or blood clot from obstructing the catheter. While a variety of different schedules exist, a commonly practiced approach is to flush the catheter with a fill volume of 10–20 ml/kg on a weekly basis until regular dialysis is initiated [92]. If substantial blood is noted in the effluent immediately after the insertion, it is advisable to flush the catheter within 24 hours of the surgical procedure.

Chronic Exit-Site Care

The goal of chronic exit-site care is to prevent the development of exit-site/tunnel infections. The SCOPE Collaborative has evaluated the frequency of exit-site infections in more than 700 children on PD and found a rate of 0.25 exit-site infections per dialysis year [93]. As suggested by Twardowski and Prowant, exit-site care consists of assessment of the exit site, cleansing the exit site, immobilizing the catheter, and protecting the exit site and tunnel from trauma [84, 94]. SCOPE has also emphasized the importance of hand hygiene and of regularly evaluating the exit site using standardized criteria [95]. In adults, it is recommended that exit-site care occur at least twice weekly, and always after a shower [10]. Cleansing agents that have been used include soap and water, povidone-iodine, chlorhexidine, and electrolytic chloroxidizing solutions. To date, no one cleansing agent has been shown to be superior to the others. In addition to the direct exit-site care, data in children and adults support the use of prophylactic antibiotic agents to decrease the incidence of *S. aureus* carriage in patients [53]. The application of either mupirocin or gentamicin creams to the catheter exit site has been efficacious in decreasing exit-site/tunnel infections, the latter agent in particular against Gram-negative infections [96–101]. Alternating mupirocin and gentamicin has been found to be associated with an increased risk for fungal peritonitis vs. gentamicin alone [102].

Mechanical Complications

Mechanical complications are generally felt to be the second most common reason (after infection) for PD catheter failure. In an analysis of 452 PD catheter revisions in children, Borzych-Duzalka et al. found that mechanical malfunction was the reason for revision in 60% of cases and access dysfunction secondary to mechanical causes doubled the risk of technique failure compared with infectious causes [14]. The mechanical complications include obstruction of the catheter by omentum, migration of the catheter out of the pelvis, and blockage of the catheter by fibrin or clots. The issue of obstruction by omentum has been previously reviewed and, as mentioned above, usually can be prevented by conducting a partial omentectomy or omentopexy at the time of catheter insertion [63, 103]. When omental blockage does occur, laparoscopic removal of the involved omentum can be easily accomplished. Migration of the catheter out of the pelvis can lead to poor dialysate inflow or outflow, as well as increased pain with dialysis. One approach to repositioning the catheter is through the use of interventional radiology techniques, in which a guide wire is used to move the catheter back to a workable position in the abdomen. Using this technique, Savader et al. reported that they were able to obtain a durable patency rate of 50% in those patients who experienced early catheter malposition (less than 30 days) and a durable patency rate of 82% with late malpositions (greater than 30 days) [104]. The complication rate was low (3%), with only a single episode of peritonitis. The risk for migration of the catheter can be lessened by the addition of rectus tunneling at the time of catheter insertion. Also, if there are recurrent problems with catheter migration, the catheter can be secured laparoscopically with a suture in the pelvis [63].

Our center has used a laparoscopic approach to non-functioning PD catheters. In patients who have had no previous abdominal procedures besides the peritoneal catheter placement, we create a pneumoperitoneum by insufflating through the malpositioned PD catheter. Once a pneumoperitoneum is achieved, a 3 mm port is placed in the left upper quadrant, and a 3 mm laparoscope is inserted. A stab wound is then made in the right upper quadrant and a 3 mm grasper is inserted. The catheter can then be manipulated under direct vision and repositioned back into the pelvis. Any adhesions that are encountered during the repositioning of the catheter are lysed at the same time, and any obstructing omentum can be removed via the port or stab site. This technique avoids a large incision in the peritoneum, thus allowing a rapid return to dialysis.

For catheters that are occluded by fibrin or blood clot, tissue plasminogen activator (tPA) has been shown to be very effective in unblocking these catheters. Two milligrams of TPA is reconstituted in 40 cm^3 of normal saline and is instilled in the catheter for 1 h. This has resulted in the restoration of patency in 57% of catheters [105–107].

Exit-Site Infection, Tunnel Infection, and Peritonitis

Catheter exit-site/tunnel infections and peritonitis are a significant cause of catheter failure. The Italian PD registry documented catheter infections as the most common catheter-related complication, with a prevalence of 73.2% and an incidence of 1 episode/27.4 patient-months [4]. As noted above, the SCOPE Collaborative recently found an annualized overall exit-site infection rate of 0.25 (equivalent to 1 episode/48 patient-months), with 69% of the infections involving the exit site alone, 23% involving only the catheter tunnel, and 8% involving both locations [93]. The goal in all cases should be the prevention of infection by following published recommendations regarding catheter insertion and care and by regular exit-site monitoring with a scoring system [53]. If, however, an infection does occur, medical management is typically successful [10, 53, 108]. Oral antibiotics that may be used for the treatment of exit-site/tunnel infections in children are described in Table 12.3 [53]. Daily exit-site care is also recommended when an infection is present [10]. In situations in which oral antibiotic therapy of an exit-site infection is unsuccessful or when it has been accompanied by a tunnel infection, intravenous or intraperitoneal antibiotic therapy should be considered.

Table 12.3 Oral antibiotics used in exit-site and tunnel infections

Antibiotic	Recommended dose	Dose frequency	Per-dose maximum
Amoxicillin	10–20 mg/kg/day	Daily	1,000 mg
Cephalexin	10–20 mg/kg/day	Daily or 2 times daily	1,000 mg
Ciprofloxacin	10–15 mg/kg/day	Daily	500 mg
Clarithromycin	7.5 mg/kg/day	Daily or 2 times daily	500 mg
Clindamycin	30 mg/kg/day	3 times daily	600 mg
Dicloxacillin		4 times daily	500 mg
<40 kg	12–50 mg/kg/day		
>40 kg	125–500 mg/dose		
Erythromycin (as base)	30–50 mg/kg/day	3 or 4 times daily	500 mg
Fluconazole	6 mg/kg/day	Every 24–48 h	400 mg
Levofloxacin	10 mg/kg	Every 48 h	Day 1 500 mg. then 250 mg
Linezolid			600 mg
<5 years	10 mg/kg/dose	3 times daily	
5–11 years	10mg/kg/dose	2 times daily	
≥12 years	600 mg/dose	2 times daily	
Metronidazole	30 mg/kg/day	3 times daily	500 mg
Rifampin[a]	10–20 mg/kg/day	2 times daily	600 mg
Trimethoprim-sulfamethoxazole (based on TMP)	5–10 mg/kg/day	Daily	80 mg

Used with permission from Warady et al. [53]

[a]Should not be used as monotherapy, or used routinely in areas in which tuberculosis is endemic

Surgical salvage of the catheter by unroofing/cuff shaving has been conducted [5, 18, 19, 109, 110]. Cuff shaving involves removing (or shaving off) the infected subcutaneous cuff and then rerouting the catheter to a different exit site remote from the infected site . Wu et al. described a technique in which the authors were able to preserve the intraperitoneal portion of the dialysis catheter and simply excise the external infected portion of the catheter [110]. This was accomplished by cutting down on the entrance site of the catheter into the peritoneum. At this point, the catheter is divided just above the internal cuff, and a new external portion with a new external cuff is then glued in place and passed out to the skin via a separate tunnel. The infected external portion of the catheter is then removed. They reported 26 catheter revisions in 23 patients with 100% resolution of the infection without interruption of peritoneal dialysis. To date, we have not had to utilize this technique, but it is intriguing to consider it for those patients in whom interruption of PD would be extraordinarily difficult.

The more standard surgical intervention for infection would be complete removal of the catheter when there is refractory peritonitis, fungal peritonitis, or a refractory catheter exit-site/tunnel infection [5, 53]. Preservation of the peritoneum should always take precedence over preservation of the catheter. In those patients in whom the infection is caused by a Gram-positive organism and the dialysate white blood cell count is $<100/mm^3$, catheter removal and replacement can occur as a single procedure under antibiotic coverage [111–113]. In contrast, fungal peritonitis and Gram-negative infections mandate that there is at least a 2–3-week interval between removal and reinsertion.

PD Catheter Care Post-Kidney Transplantation

If the PD catheter is not removed at the time of kidney transplantation, it is recommended that dressing care occur weekly during the post-transplant period. In most cases, catheters are removed within 4 weeks following successful kidney transplantation. It is not necessary to obtain routine PD cultures. While two studies noted an absence of catheter infections after transplantation if the PD catheters were left in place but not used, one of the studies did find an increased incidence of catheter infections after the first post-transplant month [114, 115]. They also noted that the majority of complications that would require the use of the catheter occurred within the first month. For this reason, they advocate and we agree that the peritoneal catheter can be safely left in place for 1 month, after which time it should be removed if it is no longer needed.

Complications with PD Catheter Removal

An interesting short report by Korzets et al. makes the case that the removal of a PD catheter can be associated with significant complications [116]. In their series of 40 catheter removals, 10 (25%) of the procedures were associated with complications, and 8 of these required further surgical intervention. Half of their complications were related to bleeding. Their usual technique was to remove the PD catheter under local anesthesia, which they felt contributed significantly to their complication rate. They also make a strong case against using traction as the removal technique because of the complications of a retained cuff and subsequent infection. The surgeon removing the catheter must be aware of the device type and implant procedure and recognize that the more complex the catheter design, the more difficult the removal. In summary, the removal of a PD catheter is a real operation that should be done in the operating room with anesthesia, and it requires strict attention to detail to prevent annoying but potentially significant complications that could require a return to the operating room.

Conclusion

The peritoneal catheter is the lifeline for the patient receiving peritoneal dialysis. Attention to detail is, in turn, necessary for everything from the selection of the best location for the exit site to the prophylactic measures used to prevent infectious complications. The establishment of a catheter "team" with a select group of participating surgeons and the regular evaluation of treatment results are initiatives designed to optimize the function of this important component of PD.

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