Chapter 8
Peritoneal Dialysis Access: Catheters and Placement

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Being able to use peritoneal dialysis (PD) successfully as a mode of kidney replacement therapy requires a functional and durable access to the peritoneal cavity. Access is provided by a catheter device that bridges the abdominal wall to serve as a conduit for infusion and drainage of dialysis solutions. This chapter will focus on current practices, describing the most commonly used catheter types, patient-specific catheter selection, and catheter placement methods.

Catheters

The majority of catheters are constructed from silicone rubber, a material well-recognized for its biocompatibility and biodurability. Erosion of silicone catheters due to the use of topical antibiotics at the exit site has been reported but appears to be a rare complication [1]. The most commonly used PD catheter types are illustrated in Fig. 8.1. The standard double Dacron (polyester) cuff, straight- and coiled-tip catheters with straight or preformed arc bend intercuff segments constitute the core of PD access devices used around the world (Fig. 8.1a, b). Two-piece extended catheters were originally designed to provide a presternal exit site (Fig. 8.1c) [2]. The extended catheter system is comprised of a one-cuff abdominal catheter segment that attaches to a two-cuff subcutaneous extension segment using a double-barbed titanium connector. Extended catheters permit remote location of the exit site away from the usual lower abdominal sites to the upper abdomen, presternal area, and back regions [2–4]. This placement of the exit site away from the abdomen can be helpful for patients with an ostomy or rolls of pannus.

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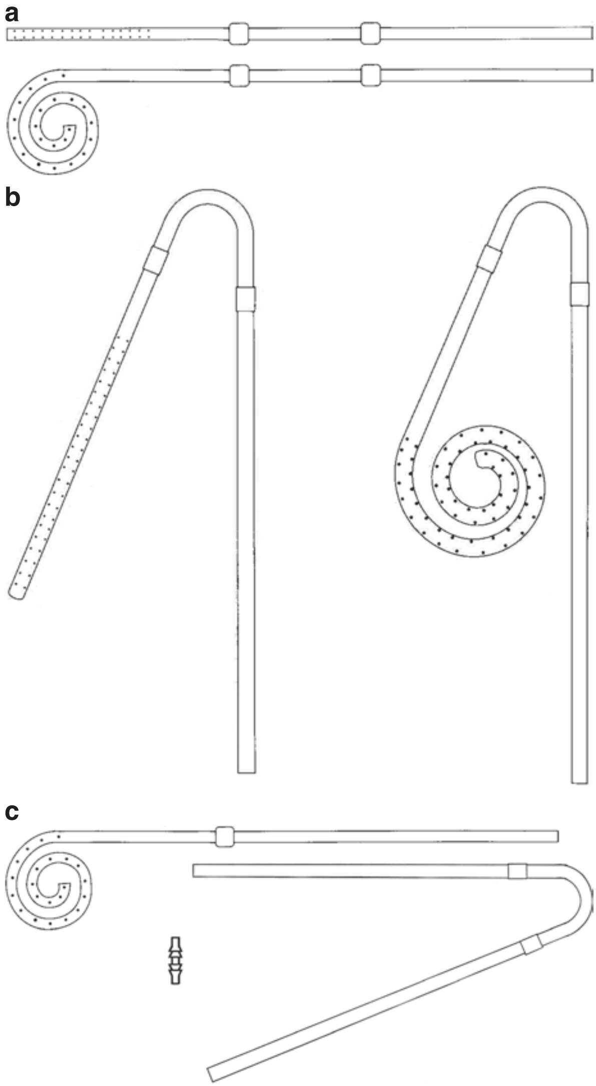

Fig. 8.1 Shown are commonly used peritoneal catheters. (**a**) Catheters with straight intercuff segment, two cuffs, and straight or coiled tips. (**b**) Catheters with preformed intercuff arc bend, two cuffs, and straight or coiled tips. (**c**) Extended catheter with one cuff, coiled-tip abdominal catheter, two-cuff extension catheter with preformed intercuff arc bend, and titanium double-barbed connector. (Reprinted from Crabtree et al. [42] with permission from Multimed, Inc.)

A number of adaptations of the standard catheter designs have been made in an attempt to address the common mechanical problems of tip migration, pericatheter leaks, and tissue attachment. However, none of these other configurations has convincingly proven beneficial over the standard catheter designs shown in Fig. 8.1 but increases device cost, adds difficulty to insertion and removal, and is not globally available.

Catheter Selection

Patients present with a range of body sizes and shapes, medical conditions, and other special needs that make it unrealistic to expect that one catheter type can serve all. The choice of catheter type should take into consideration the patient's belt line, obesity, skin creases and folds, chronic skin conditions, intestinal stomas, gastrostomy tubes, incontinence, physical limitations, bathing habits, and occupation. This requires that the peritoneal dialysis access team be familiar with a basic inventory of catheter types to enable patient-specific customization of the peritoneal access and provides optimal pelvic position of the catheter tip and flexibility in exit site location. Poor catheter choice can result in flow dysfunction, flow pain, and exit site locations prone to infection, making inaccessible to the patient [5, 6]. Practical applications of a basic catheter inventory are illustrated in Fig. 8.2.

The most suitable choice of catheter is the one that produces the best balance of pelvic location of the catheter tip, exit site in a low infection-risk zone easily visible and manageable by the patient, and permits insertion through the abdominal wall with the least amount of tubing stress. This choice must take into consideration not only the patient's physical characteristics and clinical conditions but also the dimensions of the catheter device.

The catheter insertion site and the length of intraperitoneal tubing determine the pelvic position of the catheter tip. Overly deep placement of tubing in the pelvis can be attributed frequently to using the umbilicus as a landmark for catheter insertion and not taking into account the dimensions of the catheter tubing. Excessively deep pelvic placement of the catheter, wedging the tip between the rectum and bladder or uterus, can lead to extrinsic compression of the catheter side holes by these structures resulting in flow dysfunction and pain at the end of effluent drain, especially in combination with the hydraulic suction of automated peritoneal dialysis [6]. To avoid this mistake, the pubic symphysis is recommended as the reference point for optimal position of the catheter tip in the upper part of the true pelvis [7]. With the patient supine and the catheter tubing placed in the paramedian plane, the upper extent of the catheter tip end that is to rest in the upper portion of the true pelvic bowl is aligned with the upper border of the pubic symphysis bone (Fig. 8.3). For straight-tip catheters, preferably a design with 15 cm of tubing length beyond the deep cuff, a point 5 cm from the tip of the catheter is aligned with the pubic symphysis upper border. With coiled-tip catheters, the upper border of the coil is aligned with the upper border of the pubic symphysis. The insertion incision is indicated by marking the upper border of the deep cuff of the catheter in the paramedian plane. This skin incision site will intercept the musculofascial layer at the proper distance above the true pelvis [7].

The incision site will also determine what exit sites can be achieved by the device in question. Catheters with a preformed swan neck bend in the intramural segment must precisely follow the arc configuration, selecting an exit site location 2–4 cm

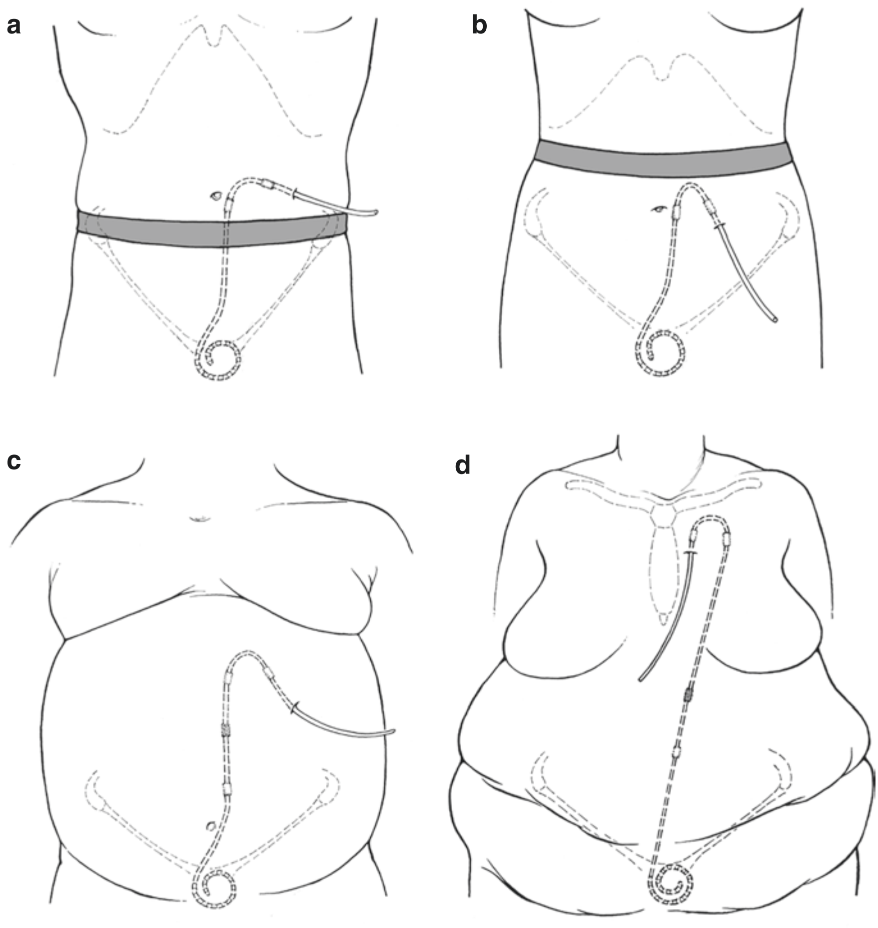

Fig. 8.2 Practical applications of a basic catheter inventory. (**a**) Straight intercuff segment catheter with laterally directed exit site emerging above a low-lying belt line. (**b**) Preformed swan neck intercuff arc bend catheter with downwardly directed exit site emerging below a high-lying belt line. (**c**) Extended catheter with upper abdominal exit site for an obese rotund abdomen, lower abdominal skin folds, or incontinence. (**d**) Extended catheter with presternal exit site for severe obesity, multiple abdominal skin folds, intestinal stomas, or incontinence. (Reprinted from Crabtree and Chow [43] with permission from Elsevier)

beyond the superficial cuff in line with the external limb of the catheter. Catheters with straight intramural segments are best limited to a gentle laterally directed subcutaneous arc in order to avoid inducing excessive forces disrupting tensile memory that can potentially lead to catheter tip migration or superficial cuff extrusion [7]. The exit site is selected 2–4 cm beyond the superficial cuff. A prospective cohort study demonstrated no difference between downward and laterally directed exit

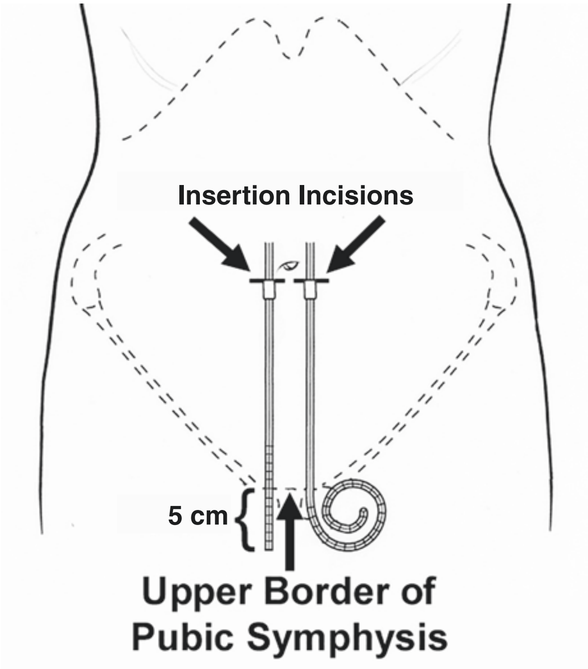

Fig. 8.3 Schematic of a supine patient showing the method in which the catheter insertion site and deep cuff location are determined in order to achieve proper pelvic position of the catheter tip. For straight-tip catheters, ideally a design with 15 cm of tubing length beyond the deep cuff, a point 5 cm from the tip of the catheter is aligned with the pubic symphysis upper border. With coiled-tip catheters, the upper border of the coil is aligned with the upper border of the pubic symphysis. (Reprinted from Crabtree et al. [42] with permission from Multimed, Inc.)

sites with regard to rates of exit site and tunnel infections, peritonitis, and catheter loss [8].

After determining the insertion site to achieve optimal pelvic position of the catheter tip and the exit site that can be reached from this location, the patient is examined in a sitting position. The selected exit site of the catheter being tested must be in a location easily visible to the patient, not within the belt line, inside a skin crease, or on the blind side or apex of an obese skin fold. If the available inventory of single-piece catheters cannot produce both satisfactory pelvic position and exit site location, device selection shifts to a two-piece extended catheter to remotely locate the exit site away from the lower abdominal region to the upper abdomen or upper chest while retaining optimal position of the catheter tip [9, 10].

Instead of the cumbersome use of sample catheters to determine the insertion site that produces optimal catheter tip position and exit site location, a process of stencil-based preoperative mapping is emerging, using marking stencils to provide a reliable and reproducible method of catheter selection [11]. Marking stencils are provided by some dialysis catheter manufacturers for their most commonly used coiled-tip catheter designs. Stencils permit accurate and reproducible association of the catheter design elements to anatomical landmarks to assist in determining the best catheter style and insertion site that will produce optimal pelvic position of the catheter tip and ideal exit site location. In addition to the preoperative evaluation for catheter selection, the marking stencil is used again at the time of the catheter placement procedure to retrace the previously determined insertion incision, tunnel configuration, and exit site location [12].

The PD access team of each center should agree on a basic catheter inventory and confirm that these specific items are made available for the peritoneal access procedure. A protocol for preoperative mapping should be developed to assure that the patient receives the most appropriate catheter type from this inventory.

Catheter Insertion

Implantation procedures for PD catheters include percutaneous needle-guidewire, open surgical dissection, peritoneoscopy, and surgical laparoscopy. Add-on techniques of extended catheter placement and catheter embedment can be incorporated into any of these procedures. Each method will be summarized followed by a description of completion steps in the placement procedure that are common to all approaches. Regardless of the approach used, observance of a number of details is required to assure the best opportunity for creating a successful long-term peritoneal access. A best practice checklist for preoperative preparation and peritoneal catheter placement is provided in Table 8.1.

Percutaneous Needle-Guidewire Technique

Placement of catheters by blind percutaneous puncture is performed using a modification of the Seldinger technique. The convenience of this approach is that it can be performed at the bedside under local anesthesia using prepackaged self-contained kits that include the dialysis catheter. Often, the technique includes prefilling the abdomen with dialysis or saline solution instilled through an introducer needle inserted through an infraumbilical or paramedian incision [13, 14]. Alternatively, a Veress needle may be used to perform the prefill, or the prefill step may be skipped altogether [15]. A guidewire is passed through the needle into the peritoneal cavity and directed toward the pelvis. The needle is withdrawn. A dilator with overlying peel-away sheath is advanced through the fascia over the guidewire. The guidewire and dilator are withdrawn from the sheath. Optionally, to facilitate insertion, the catheter can be straightened and stiffened by insertion of an internal stylet. If a long guidewire is used, it can be left in the peel-away sheath, and the catheter is threaded over the guidewire. The dialysis catheter is directed through the sheath toward the pelvis. As the deep catheter cuff advances, the sheath is peeled away. The deep cuff is advanced to the level of the fascia.

The addition of ultrasound and fluoroscopic guidance to the percutaneous approach has greatly increased its safety and utility. Comprehensive preprocedural

Table 8.1 Checklist for patient preparation and peritoneal catheter implantation

Preoperative assessment performed by a multidisciplinary PD access team to select the most appropriate catheter type, insertion site, exit site location, and implantation technique
Implement bowel program to prevent perioperative constipation
Shower on the day of procedure with chlorhexidine soap wash of the planned surgical site
If hair removal is necessary, use electric clippers
Empty the bladder before procedure; otherwise, Foley catheter should be inserted
Single preoperative dose of prophylactic antibiotic to provide antistaphylococcal coverage
Operative personnel are attired in cap, mask, sterile gown, and gloves
Surgical site is prepped with chlorhexidine-gluconate scrub, povidone-iodine (gel or scrub), or other suitable antiseptic agent and sterile drapes applied around the surgical field
Peritoneal catheter is rinsed and flushed with saline and air squeezed out of the Dacron cuffs by rolling the submerged cuffs between fingers
Paramedian insertion of the catheter through the body of the rectus muscle with deep catheter cuff within or below rectus muscle
Pelvic location of the catheter tip
Placement of purse-string suture(s) around the catheter at the level of the peritoneum and posterior rectus sheath and/or the anterior rectus sheath
Catheter flow test performed to confirm acceptable function
Subcutaneous tunneling instrument should not exceed the diameter of the catheter
Exit site located ≥2 cm beyond superficial cuff
Skin exit site directed lateral or downward
Exit site should be smallest skin hole possible that allows passage of the catheter
No catheter-anchoring sutures at the exit site
Attach dialysis unit's preferred catheter adapter and transfer set at time of procedure
Exit site protected and catheter immobilized by nonocclusive dressing

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assessment utilizing ultrasound may permit objective case selection for safe percutaneous insertion of catheters in patients who may have otherwise been excluded because of prior abdominal surgery or obesity [16]. During the course of the access procedure, ultrasonography can be used to identify and avoid injury to the inferior epigastric vessels and bowel loops. Fluoroscopy permits confirmation of needle entry into the peritoneal cavity by observing the flow of injected contrast solution around bowel loops [17]. The use of imaging techniques eliminates the need to perform a prefill. The retrovesical space is identified by contrast pooling in this dependent location. The guidewire and catheter are advanced to this site. The remainder of the procedure proceeds as described for blind placement. Although the radiopaque tubing stripe permits fluoroscopic imaging of the final catheter configuration, the proximity of adhesions or omentum cannot be assessed. Practitioners of percutaneous guidewire placement techniques often leave the deep catheter cuff external to the fascia to avoid having to dissect the cuff from the rectus sheath and muscle if subsequent catheter removal is required. After testing flow function, the catheter is then tunneled subcutaneously to the selected exit site.

Open Surgical Dissection

Placement of the PD catheter by open surgical dissection can be performed under local, regional, or general anesthesia [18]. A transverse or vertical paramedian incision is made through the skin, subcutaneous tissues, and anterior rectus sheath. The underlying muscle fibers are split to expose the posterior rectus sheath. A small hole is made through the posterior sheath and peritoneum to enter the peritoneal cavity. A purse-string suture is placed around the opening. The catheter, usually straightened over an internal stylet, is advanced through the peritoneal incision toward the pelvis. The stylet is partially withdrawn as the catheter is advanced until the deep cuff abuts the posterior fascia. After satisfactory placement has been achieved, the stylet is completely withdrawn, and the purse-string suture is tied. (The purse-string suture helps to secure the catheter and prevent leakage of dialysis fluid.) The catheter tubing emerges through the anterior rectus sheath incision or through a separate puncture in the anterior sheath. The fascia is sutured, and the catheter is tunneled subcutaneously to the selected exit site following a satisfactory test of flow function.

Peritoneoscopic Procedure

The peritoneoscopic approach is a proprietary laparoscopic-assisted technique of peritoneal catheter placement (Y-TEC, Merit Medical, South Jordan, UT, USA). Although peritoneoscopy and laparoscopy are synonymous terms, the word peritoneoscopic has been retained by interventional nephrologists to indicate the Y-TEC approach [19]. The procedure is typically performed in a treatment room under local anesthesia. A 2.5-mm trocar with an overlying plastic sleeve is inserted percutaneously into the peritoneal cavity through a paramedian incision. The obturator of the trocar is removed, permitting insertion of a 2.2-mm laparoscope to confirm peritoneal entry. The scope is withdrawn, and 0.6–1.5 L of room air is pumped into the abdomen with a syringe. The scope is reinserted, and the overlying cannula and plastic sleeve are visually directed into an identified clear area within the peritoneal cavity. The scope and cannula are withdrawn, leaving the expandable plastic sleeve to serve as a conduit for insertion of the catheter straightened over a stylet toward the previously identified clear area. The plastic sleeve is withdrawn and the deep cuff is pushed into the rectus sheath. After testing flow function, the catheter is tunneled subcutaneously to the selected exit site.

Surgical Laparoscopy

Laparoscopy provides a minimally invasive approach with complete visualization of the peritoneal cavity during the catheter implantation procedure. Laparoscopic procedures are performed under general anesthesia in an operating room environment. Surgical laparoscopy uses either a basic or advanced approach to providing PD access. Basic laparoscopic catheter placement is defined as using the laparoscope to merely witness the positioning of the catheter tip within the peritoneal cavity in real time [20, 21], whereas advanced laparoscopic implantation utilizes additional preemptive procedures to minimize the risk of mechanical catheter complications [22–24]. With either approach, a pneumoperitoneum is created by insufflating CO_2 gas through an abdominal wall puncture site using a Veress needle or optical trocar device placed at a location separate from the point of intended catheter insertion. Alternatively, especially when patients have had previous midline abdominal surgery or peritonitis, initial port placement and gas insufflation can be performed by open dissection cutdown to the peritoneal cavity. The laparoscope is inserted at this remote location to guide placement of the PD catheter into the pelvis through a second port device placed at the designated catheter insertion incision. Completion of catheter positioning is the endpoint of basic laparoscopy.

Advanced laparoscopic catheter placement employs proactive adjunctive techniques. Laparoscopically guided tunneling of a port device through the rectus sheath permits placement of the catheter in a long musculofascial tunnel directed toward the pelvis and effectively prevents catheter tip migration, reducing the risk of pericatheter hernias and pericatheter leaks [22–24]. Observed redundant omentum that lies in proximity of the catheter tip can be displaced from the pelvis into the upper abdomen and fixed to the abdominal wall or falciform ligament or folded upon itself (omentopexy) [25–27]. Intraperitoneal adhesions that may affect completeness of dialysate drainage can be divided. Intraperitoneal structures that siphon up to the catheter tip during the intraoperative irrigation test can be laparoscopically resected, e.g., *appendices epiploicae* of the sigmoid colon and Fallopian tubes [25, 28]. Redundant and bulky rectosigmoid colon blocking the pelvic inlet can be suspended along the lateral abdominal wall (colopexy) [25]. Previously unsuspected abdominal wall hernias and patent *processus vaginalis* can be identified and repaired at the time of the catheter placement procedure [24, 25].

The deep cuff of the catheter is positioned in the rectus muscle just below its point of entry through the anterior fascial sheath. A purse-string fascial suture around the catheter at the level of the anterior sheath is recommended to further reduce the risk of pericatheter leak [25]. The pneumoperitoneum is released, but laparoscopic ports are left in place until a test irrigation of the catheter demonstrates successful flow function. After any indicated adjunctive procedures are completed, the catheter is tunneled subcutaneously to the selected exit site.

Extended Two-Piece Catheter Insertion

The abdominal segment of the extended catheter (Fig. 8.1c) can be implanted by any of the above-described insertion techniques [9, 10, 29, 30]. A secondary incision is made in the vicinity of the planned upper abdominal, presternal, or back exit site. The measured distance between the abdominal insertion incision and the secondary incision is used to determine how much tubing length will be trimmed from one or both of the catheter segments in order to correctly span the distance. The trimmed catheters are joined with a supplied double-barbed titanium connector, and the linked catheter segments are tunneled on the surface of the fascia from the abdominal insertion site to the remote secondary incision with a tunneling rod. The extension catheter is then tunneled from the secondary incision to the exit site using a stylet to complete the procedure.

Catheter Embedding

Commonly described as the Moncrief-Popovich technique [31], catheter embedding consists of implanting a PD catheter far in advance of anticipated need. Instead of leaving the external limb of the catheter exteriorized through the skin, it is embedded in a subcutaneous track. When kidney function declines to the point of needing to initiate dialysis, the external limb of the catheter is retrieved through a small skin incision that can be performed at the bedside or in the office.

Because the catheter has been allowed extended healing time within the abdominal wall, the patient is able to proceed directly to full volume peritoneal dialysis without the necessity of a break-in period. Catheter embedment can serve as a strategy for growing PD programs by achieving early patient commitment to their modality choice. The need for insertion of vascular catheters and temporary hemodialysis can be avoided in patients previously implanted with an embedded catheter. The embedding technique permits more efficient surgical scheduling of catheter placement as an elective nonurgent procedure and helps to reduce stress on operating room access. Disadvantages of the catheter embedding strategy include the need for two procedures (implantation and externalization) as opposed to one and the possibility of futile placement in the event of an adverse change in the patient's condition during the time period that the catheter is embedded or the patient undergoes a preemptive kidney transplant and the catheter is never used [32, 33].

Catheter embedding can be incorporated into any of the implantation approaches using any catheter type. The catheter is temporarily externalized through the future skin exit site prior to embedment. The exit site scar serves as a landmark to know where to come back to for externalization. After acceptable flow function of the catheter is confirmed, the tubing is infused with heparin, plugged, and embedded in the subcutaneous tissue. To minimize the risk of hematoma or seroma and to facilitate later retrieval, the catheter should be embedded in a linear or curvilinear subcutaneous track using a tunneling stylet as opposed to curling the tubing into a subcutaneous pocket [34]. Embedding should not be performed if anticipated need for dialysis is <4 weeks or if the patient has had previous major abdominal surgery or peritonitis where adhesiolysis may likely leave blood in the peritoneal cavity. Externalization of embedded catheters is easily accommodated in the clinic provided that a suitable procedure room is available. Catheters have been embedded for months to years with an 85–93% immediate function rate upon externalization [32, 34–36]. Catheter dysfunction is usually due to adhesions or intraluminal fibrin clots. Overall, 94–99% are successfully used for dialysis after radiologic or laparoscopic revision of nonfunctioning catheters [32, 34, 36].

Procedure Elements Common to All Approaches

Following catheter insertion by one of the four approaches, it is important to test catheter patency and flow function before accepting placement. A variety of clinical practices exist for testing hydraulic function. A limited approach is syringe irrigation of the catheter with a small volume of saline. Easy return of some of this fluid and changes in the level of an air-fluid interface in the catheter during respiration confirms that the catheter is located in the peritoneum and has no kinks. A more complete test of flow function consists of infusing 500–1000 ml of saline or dialysate and observing for unimpeded inflow and outflow, allowing a 100–200-ml residual volume to avoid leaving peritoneal structures siphoned up to the catheter side holes. Larger irrigation volumes may permit an opportunity for redundant omentum, *appendices epiploicae*, or uterine tubes to drift up to the catheter tip and manifest as a cause for slow or low-volume drainage. Repositioning the catheter may resolve the flow dysfunction, whereas laparoscopic techniques can definitively deal with these identified sources of obstruction and reduce the risk for future mechanical complications. The larger irrigation volume also provides an assessment of hemostasis and washes out any accumulation of blood from the procedure.

After demonstrating satisfactory hydraulic function, the catheter is tunneled to the exit site using a stylet device that does not exceed the diameter of the catheter. Available from most major catheter manufacturers, the Faller stylet is specifically designed for subcutaneous tunneling of catheters and can be advanced through the skin without making a prior incision. The use of hemostat clamps is to be avoided. Patency of the catheter should be checked following tunneling with a syringe flush of saline to demonstrate that the tubing was not kinked during its subcutaneous passage.

The PD unit's preferred catheter adapter and transfer set should be attached at the time of the catheter placement procedure. Although a plastic adapter is provided with the catheter, some PD units prefer a separately supplied titanium adapter. Attaching the preferred adapter and transfer set at the time of the procedure spares the PD nursing staff from having to go through meticulous sterile preparation procedures to make these necessary connections and risk iatrogenic peritonitis. A final flush of the catheter and attachments with heparin solution may help to minimize the risk of postoperative fibrin plugs.

At the conclusion of the procedure, the catheter and transfer set must be adequately immobilized to prevent traction at the exit site. Catheter-anchoring sutures should not be used. Instead, the catheter can be effectively immobilized with medical adhesive tincture and sterile adhesive strips and a nonocclusive gauze dressing sufficient in size to further secure the catheter.

Similar to hydraulic testing, there is a wide range of postoperative catheter flushing policies among PD centers, if performed at all [37]. The most common practices include flushing with saline or dialysis solution, using 500- to 1000-ml volumes with added heparin, 1000 units/L. The primary reason for flushing is to prevent fibrin or blood clot obstruction of the catheter. A flexible approach can be taken based upon patient conditions at the time of the catheter placement procedure. If bloody effluent is recognized during hydraulic testing and/or the patient undergoes multiple interventions during catheter placement that increases the risk of bleeding, it is advisable to flush the catheter within 24 hours, repeating the lavage until clearing of blood is demonstrated. Unless there is persistence of blood in the effluent, flushes can be extended to weekly intervals until PD is started. If catheter placement is uneventful with negligible blood in the test irrigant, initial flush is performed at 1 week, and then weekly until dialysis is initiated.

Choosing a Catheter Implantation Approach

Operator performance aside, when catheter placement by percutaneous needle-guidewire with/without image guidance, open surgical dissection, peritoneoscopy, and basic laparoscopy are compared with identical study populations, the reported outcomes are not that different [15, 20, 21, 38–40]. However, a recent meta-analysis comparing open dissection, basic, and advanced laparoscopic catheter implantation procedures demonstrated significantly superior outcomes for advanced laparoscopy over the other two approaches with regard to catheter tip migration, flow obstruction, and catheter survival [41]. The strength of advanced laparoscopic implantation is the adjunctive procedures that are enabled by this approach. Nevertheless, the chosen implantation technique must take into consideration patient factors, e.g., anesthetic risk and magnitude of any previous abdominal surgery. Other aspects that influence choice include facility resources supporting the procedure and the expertise and availability of the operating team. Table 8.2 offers guidelines for selecting a PD catheter insertion approach.

Table 8.2 Suggested guidelines for selecting a peritoneal dialysis catheter insertion approach

	Previous major surgery or peritonitis (order of suggested technique)	No previous major surgery or peritonitis (order of suggested technique)
Patient suitable for general anesthesia	Advanced laparoscopic Open surgical dissection	Advanced laparoscopic Image-guided percutaneous Open surgical dissection or peritoneoscopic Percutaneous without image guidance
Patient only suitable for local anesthesia/sedation	Open surgical dissection	Image-guided percutaneous Open surgical dissection or peritoneoscopic Percutaneous without image guidance

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