Chronic Peritoneal Dialysis Catheters: Overview of Design, Placement, and Removal Procedures

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ABSTRACT

The success of chronic peritoneal dialysis (PD) depends to a large extent on the success of the chronic PD access device. For the nephrologist placing and removing PD catheters, or for the nephrologist advising surgeons in this role, this article provides a review of designs of PD catheters and differences in function and complications, methods of insertion of PD catheters and relation to catheter outcomes, techniques for “burying” the external portion of the PD catheter and benefits of this technique, and techniques for removing PD catheters. As nephrologists become more closely involved in the creation, monitoring, and maintenance of access devices for end-stage renal disease (ESRD) patients, the successful function of these devices will increase. Nephrologists should make the critical decisions regarding the choice of access devices and methods for placement as they do for the choice to remove such access devices.

Types of Chronic Peritoneal Catheters

Chronic peritoneal dialysis (PD) catheters are the most successful of all transcutaneous access devices, with longevity and successful function measured in years rather than days to months. They are constructed of soft materials like silicone rubber or polyurethane. The intraperitoneal portion usually contains 1 mm side holes, but one version has linear grooves or slots rather than side holes. All chronic PD catheters have one or two extraperitoneal Dacron cuffs that promote a local inflammatory response. In a unique example of beneficial bioincompatibility, the sclerotic process produces a fibrous plug to fix the catheter in position, prevent fluid leaks, and prevent bacterial migration around the catheter. In spite of general success, peritoneal access failure is still a source of frustration for all PD programs, and catheter failure is the reason for “dropout” from such programs in about 25% of patients. Increasing the success of a continuous ambulatory peritoneal dialysis (CAPD) program requires optimizing the function of peritoneal catheters. Currently the method of placement of the catheter has more effect on the outcome of the catheter than its choice (1,2).

As shown in Fig. 1, there appears at first to be a bewildering variety of chronic peritoneal catheters. However, each portion of the catheter has only a few basic design options (3). There are four designs for the intraperitoneal portion: straight Tenckhoff, with an 8 cm portion containing 1 mm side holes; curled Tenckhoff, with a coiled 16 cm portion containing 1 mm side holes; straight Tenckhoff, with perpendicular discs (Toronto-Western, rarely used); and T-fluted catheter (Ash Advantage) with grooved limbs positioned against the parietal peritoneum. There are three basic shapes for the subcutaneous portion between the muscle wall and the skin exit site: straight, or gently curved; a 150-degree bend or arc (Swan Neck), and a 90-degree bend, with another 90-degree bend at the peritoneal surface (Cruz “Pail Handle” catheter). There are three positions and designs for Dacron cuffs: a single cuff around the catheter, usually placed in the rectus muscle but sometimes on the outer surface of the rectus; dual cuffs around the catheter, one in the rectus muscle and the other in the subcutaneous tissue; and a disc-and-ball deep cuff, with parietal peritoneum sewn between the Dacron disc and silicone ball (Toronto-Western and Missouri catheters). There are three internal diameters of PD catheters, each having an outer diameter of approximately 5 mm (see Fig. 2): 2.6 mm, the standard Tenckhoff catheter size; 3.1 mm, the Cruz catheter; and 3.5 mm, the Flexneck catheter. There are two materials of construction: silicone rubber (nearly all catheters) and polyurethane (Cruz catheter).

The various intraperitoneal designs were all created to diminish outflow obstruction due to the normal diminution in flow that occurs as peritoneal surfaces approach the catheter or due to omental attachment to the catheter. The shape of the curled Tenckhoff catheter and the discs of the Toronto-Western catheter to some degree hold visceral peritoneal surfaces away from the side holes of...
the catheter. The grooves of the Advantage catheter distribute flow over the surface of the limbs that contact the parietal peritoneum, providing a much larger surface area for drainage than side holes provide. An irritated omentum attaches firmly to side holes of a catheter but only weakly to grooves on a catheter (as demonstrated by the Blake surgical drain, with grooves on the catheter surface).

The subcutaneous portion all of PD catheters provides a lateral or downward direction of the exit site. A lateral or downward direction minimizes the risk of exit infection. An upward-directed exit site collects debris and fluid, increasing the risk of exit site infection.

The optimal location for the standard deep cuff is within the rectus muscle (described below). The subcutaneous cuff provides additional protection from bacterial contamination of the subcutaneous tunnel. The disc-and-ball deep cuff provides security of catheter position security since, with the peritoneum sewn between the Dacron disc and intraperitoneal ball, the catheter is fixed in position and cannot migrate outward. Similarly the T shape of the Advantage catheter places the intraperitoneal limbs against the parietal peritoneum, preventing outward migration of the catheter.

The larger internal diameter of the Cruz and Flexneck catheters provides lower hydraulic resistance and more rapid dialysate flow during the early phase of outflow. In the latter part of outflow, the resistance to flow is determined mostly by the spaces formed by peritoneal surfaces as they approach the catheter. The Advantage catheter provides much larger entry ports for drainage of peritoneal fluid, and limited clinical studies have demonstrated faster drainage of the peritoneum in the early and late phases of outflow and a decrease in residual peritoneal volume at the end of outflow.

Changing the construction material of peritoneal catheters has not changed the incidence of catheter complications. Polyurethane catheters do not have a lower incidence of peritonitis or omental attachment leading to outflow failure. Polyurethane catheters generally have a weaker bond to the Dacron cuff, and loosening of this bond can create pericatheter leaks.
Proper Location of Chronic Peritoneal Catheter Components

There is general agreement on the proper location of chronic peritoneal catheter components (see Fig. 3):

- The intraperitoneal portion should be between the parietal and visceral peritoneum and directed toward the pelvis to the right or left of the bladder.
- The deep cuff should be within the medial or lateral border of the rectus sheath.
- The subcutaneous cuff should be approximately 2 cm from the skin exit site.

Placing the deep cuff within the rectus muscle promotes tissue ingrowth and therefore avoids pericatheter hernias, leaks, catheter extrusion, and exit site erosion (2–4). At the parietal peritoneal surface, the squamous epithelium reflects along the surface of the catheter to reach the deep cuff. If the deep cuff is outside the muscle wall, the peritoneal extension creates a potential or actual pericatheter hernia. At the skin surface, the stratified squamous epithelium follows the surface of the catheter until it reaches the superficial cuff. If the tunnel from the subcutaneous cuff to the exit site is longer than 2 cm, the squamous epithelium disappears before reaching the cuff and granulation tissue is left, leading to an exit site with continued “weeping” of serous fluid, and the potential for exit site infection is increased. If the subcutaneous cuff is too close to the exit site then the cuff will irritate the dermis and the exit site will be continually reddened and inflamed.

Some peritoneal catheters have components that provide greater fixation of the deep cuff within the musculature. When the Missouri and Toronto-Western catheters are placed, the parietal peritoneum is closed between the ball (inside the peritoneum) and disc (outside the peritoneum). When the T-fluted (Ash Advantage) catheter is placed, the wings open in position adjacent to the parietal peritoneum and perpendicular to the penetrating tube. With these two catheters, outward migration of the catheter is impossible.

When placing peritoneal catheters, especially by blind or peritoneoscopic approaches, it is best to choose a deep cuff location that is free of major blood vessels (Fig. 4). The superficial epigastric arteries course from the femoral artery and ligament toward the umbilicus, anterior to the rectus sheath. The inferior epigastric arteries lie behind the rectus muscles, roughly in the middle of the rectus sheath. Considering the position of these arteries, the safest locations for inserting a needle or cannula to place the catheter are in the medial or lateral borders of the rectus muscle. By physical examination, the lateral border of the rectus can be determined by asking the patient to tense the abdomen and palpating the lateral border, or for patients with weaker abdominal muscles this border is always located halfway between the anterior superior iliac spine and the umbilicus. Open squares represent the preferred and safest points for locating the deep cuff of a chronic peritoneal catheter within the medial or lateral border of the rectus muscle. Solid squares indicate the external landmarks used during blind insertion of a needle or cannula at the start of peritoneoscopic or blind catheter placement: half the distance between the anterior superior iliac spine for the lateral border of the rectus, and 2 cm below the umbilicus for the medial border of the rectus. (Adapted from Ash SR, Daugirdas JT: Peritoneal access devices. In: Daugirdas JT, Ing TS (eds). Handbook of Dialysis, 2nd ed. New York: Little, Brown, 1994:274–300; with permission.)
spine and the midline. The medial border is located approximately 1 cm from the midline, below the umbilicus. The exact location of the medial and lateral border of the rectus muscle can be determined more precisely using ultrasound (such as with the Site-Rite) by moving the probe laterally from midline to flank. Positioning the probe over potential sites for catheter placement in an orientation to detect vertical movement of the viscera also allows a qualitative assessment of motion and a determination of which sites are most freely mobile and therefore less likely to contain dense adhesions.

**PD Catheter Implantation Methods**

Chronic PD catheters are placed by one of three methods. In each case, the abdomen is thoroughly prepped, carefully draped, and general sterile technique is used (cap, mask, gown, gloves, etc.).

**Dissection**

Dissection is a surgical technique in which layers of tissue are separated under direct vision. A 3–5 cm “primary” skin incision and a 2–3 cm incision through the rectus muscle (5,6) are made. The parietal peritoneum is identified, incised, and lifted to create an air space between parietal and visceral peritoneum. The catheter and internal stylet are advanced by feel into the peritoneum, until the deep cuff is within the rectus muscle (for Tenckhoff-type catheters). For the Missouri and Toronto-Western catheters, the ball is advanced into the abdomen and the parietal peritoneum sewn between the ball and Dacron disc (5). Dissective placement is generally performed under light general anesthesia, but can be done with local anesthesia if desired.

**Blind Puncture**

The abdomen is first prefilled with fluid, and a needle is inserted through the muscle wall. Then a guide wire is placed, the tract is dilated, and the catheter is inserted through a split-sheath (similar to that used for IJ catheters). When the deep cuff stops at the external rectus, the split-sheath is separated and removed, leaving the deep cuff in a location just outside the abdominal musculature. Blind placement is done with local anesthesia. Only Tenckhoff-type catheters can be placed by blind techniques (not Missouri, Toronto-Western, or Advantage catheters).

**Peritoneoscopy**

Peritoneoscopy, in which a 2.2 mm diameter, 15 cm long peritoneoscope (Y-Tec) is used to inspect the peritoneum and choose the proper location of the peritoneal catheter, which follows the same course when the scope is removed. A cannula, internal trocar, and surrounding Quill guide are inserted into the abdomen, the intraperitoneal position confirmed using the scope, and then about 1 L of air is manually injected to create a pneumoperitoneum. The cannula is advanced between the visceral and parietal peritoneum under vision, the scope and cannula are removed, the Quill is expanded with dilators, and the peritoneal catheter is advanced through the Quill. The deep cuff enters the musculature by expanding the Quill, with the Cuff Implanter tool advancing the cuff so that the outer portion is just below the external rectus sheath (Fig. 5). Peritoneoscopic placement is also used for placement of the Advantage catheter, though the catheter can also be placed by dissection. A second spiral guide encloses the catheter with the intraperitoneal limbs folded forward. This spiral guide is advanced through the Quill guide, and when the Quill guide and spiral guide are retracted, the limbs open against the parietal peritoneum. The deep cuff is automatically positioned within the rectus muscle. Peritoneoscopic placement of Tenckhoff and Advantage catheters is generally done with local anesthesia (as opposed to laparoscopic placement).

Tunneling the catheter is similar for each method of insertion. The exit site is determined by laying the catheter over the skin in a gentle downward bend (for straight subcutaneous segment catheters) or in an arcuate course (for Swan Neck catheters). The exit site is chosen at a point 2 cm external to the subcutaneous cuff.
A “secondary” incision is made by inserting a no. 11 scalpel blade to the hub. A Tunnelor Tool or similar device is advanced through the subcutaneous fat from the secondary incision to the primary incision. The tip of the catheter is attached to the Tunnelor, and the tip brought through the secondary incision. Hemostats are lightly applied to the catheter tubing (outside the superficial cuff) and the tips of the hemostats are drawn into the tunnel. When the tips of the hemostats reach the desired position of the subcutaneous cuff, the tips are spread and the hemostat removed. The catheter is pulled through the exit site and the subcutaneous cuff is drawn into the tunnel, to rest 2 cm from the exit site.

There are advantages and disadvantages of each technique of catheter placement, and the overall success of the catheter is highly dependent upon the method of placement. Dissective techniques securely place the deep cuff within the abdominal musculature. However, the incision in the abdominal musculature requires surrounding tissues to first close the wound, then grow into the deep cuff before the deep cuff is secure. Pericutaneous leaks are frequent if the catheter is used immediately after placement. The dissective approach provides very little visualization of the peritoneal surfaces and no visualization of adhesions or assessment of spaces free of adhesions within the peritoneum. The catheter may be advanced into loops of bowel, or near adhesions, and early outflow failure of the catheter may result.

Blind placement procedures are convenient, can be performed anywhere in a hospital, and have the advantage of being low cost. Bowel perforation is an occasional complication (about 1 in 100 placements) and no visualization of the peritoneal space is provided to avoid impinging the catheter tip on adhesions or visceral surfaces. The standard procedure leaves the deep cuff outside of the abdominal musculature, not within the rectus sheath, unless specific further steps are taken, such as grasping the cuff with hemostats and driving the cuff into the rectus muscle.

Peritoneoscopic placement allows the best visualization of the peritoneal space. This avoids placing the catheter under bowel loops, under omentum or against adhesions. The Quill expands to allow the deep cuff to advance into the musculature. The Y-Tec procedure can be performed in any room in the hospital. Specialized equipment must be purchased, however, and the physician must have some training in peritoneoscopic techniques. A number of publications have described using standard laparoscopic equipment to place peritoneal catheters. The visualization of the peritoneum by using these laparoscopes is actually better than with the Y-Tec scope. Tenckhoff catheters can be placed by any of the methods described above. The disc-and-ball, Missouri, or Toronto-Western catheters, however, can only be placed by dissection techniques.

**Effects of Placement Techniques on the Success of Chronic PD Catheters**

The success of peritoneal catheters depends more on placement technique than on their design (1,3,7,8). Peritoneoscopic placement results in the lowest incidence of catheter complications and a catheter half-life of more than 3 years (3). Randomized, controlled studies have confirmed that catheter survival is approximately twice as long for those placed by peritoneoscopy versus catheters placed by dissective techniques (9,10). In these studies nephrologists placed the catheters peritoneoscopically and surgeons placed the catheters by dissection. Table 1 summarizes the results of more than 70 studies on the incidence of serious catheter complications (infection, outflow failure, and pericatheter leak) during an average follow-up of 13 months after catheter placement. Catheters included all types of Tenckhoff-type catheters and Toronto-Western catheters. Infectious complications are defined as any peritoneal or catheter infection except randomly occurring peritonitis. Results are organized according to the type of catheter and method of placement (1,3,7).

Among the methods of placement, the peritoneoscopic method (generally performed by nephrologists) has the lowest incidence of infectious complications over the life of the catheter. The decreased incidence of catheter infection may relate to the decreased amount of tissue trauma and smaller incision size of the peritoneoscopic placement versus dissective placement, and better assurance that the cuff is placed within the muscle versus blind placement. Outflow failure and leaks are comparable between peritoneoscopic placement and surgical dissection, but are higher with blind placement. This relates to the lack of peritoneal visualization during positioning of the catheter with blind techniques and the usual position of the cuff outside the rectus sheath rather than within the rectus muscle.

There are also differences in the ability for early use of catheters for supportive dialysis according to the method of placement. Peritoneoscopically placed catheters may be used for PD treatments immediately to support the patient without need for HD in almost any schedule that does not include the full volume of the peritoneum during times of activity. This includes night-time cycler therapy or overnight exchanges, but excludes full-volume CAPD (3). Surgically placed catheters can also be used immediately if the deep cuff is secured by sutures within the rectus muscle, but in general, PD is delayed for 2 weeks after placement. Catheters placed by blind techniques can be used for immediate dialysis in the immobile patient (as in a hospital bed), but a delay of 1–2 weeks is necessary in most patients before beginning PD.

**Table 1. Incidence of complications leading to removal of chronic PD catheters during the lifetime of the catheter, arranged according to method of placement (fraction of catheters placed)**

<table>
<thead>
<tr>
<th>Insertion method</th>
<th>Infections</th>
<th>Outflow failure</th>
<th>Leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind: trocar or guide wire</td>
<td>0.24</td>
<td>0.16</td>
<td>0.17</td>
</tr>
<tr>
<td>Surgical: dissection</td>
<td>0.35</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Peritoneoscopic</td>
<td>0.13</td>
<td>0.06</td>
<td>0.06</td>
</tr>
</tbody>
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Summary of 70 published studies on all types of catheters (1).
Effects of Catheter Design on the Success of the Catheter

Randomized, prospectively controlled studies have generally shown little effect of catheter design on the success of peritoneal catheters. One study by Nielsen et al. (11) demonstrated a longer 3-year survival of coiled versus straight Tenckhoff catheters. If properly placed, dual-cuff Tenckhoff catheters have a lower incidence of exit site infection and longer life span than single-cuff catheters (1,2,12), though properly placed single-cuff catheters can work as well (13). Curled Tenckhoff catheters have a lower incidence of outflow failure than straight catheters in some studies (2,11). Swan Neck catheters have a lower incidence of exit site infection than those with straight subcutaneous segments (14). Non-randomized studies of specific catheters have indicated various advantages, including that catheters with the best fixation of the deep cuff (such as the Missouri and Advantage catheters) have a very low incidence of exit site infection (7).

Some Tenckhoff catheters, such as the silicone rubber Flexneck, have a larger internal diameter and thinner walls than standard catheters (Fig. 2). Flexneck catheters are more pliable and create less tension between deep and superficial cuffs during normal patient activities. This decreased tension may result in a lower incidence of pericatheter leaks and hernias, and fewer exit site and tunnel erosions over time, but this benefit has not been proven. These catheters, like the Cruz catheter, create a higher rate of inflow and initial outflow versus the standard Tenckhoff catheters with smaller internal diameters. Rapidity of flow at the end of outflow for the Cruz catheter is also aided by the 90-degree angle of the catheter at the parietal surface, which positions the coiled portion next to the parietal peritoneal surface (2). Catheters constructed from polyurethane (such as the Cruz) have excellent strength and biocompatibility. However, the glue bonding of the Dacron cuff to the catheter may fail over 1–2 years of use, resulting in leaks and infections (3). A problem with Flexneck catheters is that they are also prone to crimping in the subcutaneous tunnel if they are angled sharply. If physicians follow a template to create a subcutaneous tunnel with a gentle downward curve, crimps in the subcutaneous tract are eliminated.

The Advantage catheter contains a straight portion which is adjacent to the parietal peritoneum, ensuring a stable position without extrusion of the deep cuff or exit site erosion (similar to the disc-and-ball catheters and the older Lifecath catheter) (15). Further, the grooves of the catheter allow fluid inflow from every direction over every part of the intraperitoneal portion. Advantage catheters placed in patients beginning PD and those with previous Tenckhoff failures demonstrate a 1-year survival of 90%, higher than the 50–80% survival for Tenckhoff catheters in numerous other studies (Fig. 6). During follow-up of 30 patients with Advantage catheters in place for up to 4 years, only 1 patient developed a pericatheter leak (resolved by delaying CAPD), and no patient developed a pericatheter hernia or late exit infection. Pericatheter leak with the Advantage catheter has only occurred in patients with evidence of catheter infection and subsequent lack of ingrowth to the catheter cuffs. The outflow rate of PD fluid is on average equal to the best functioning Tenckhoff catheters (including the large internal diameter Flexneck catheters). Outflow volume is more consistent with the Advantage catheter. In CAPD exchanges with the same glucose concentration and dwell time, the Advantage catheter has a standard deviation of 2%, versus 10% for Tenckhoff catheters. The consistent peritoneal outflow is probably due to more complete drainage of the peritoneum, with a diminished residual volume. Diminished residual volume is important, since if residual volume is decreased by 300–500 ml, the inflow volume can be increased by the same amount, thus increasing the peritoneal clearance by 10–20% without increasing patient discomfort by overfilling the abdomen.

Advantage peritoneal catheters diminish the risk of outflow failure, but do not eliminate this risk. The mechanism of outflow failure is different from Tenckhoff catheters. Omentum does not directly attach to the intraperitoneal portion of the catheter, but rather surrounds the long, slotted intraperitoneal catheter limbs and traps them against the parietal peritoneum. Infusion of iodine dye during fluoroscopy demonstrates that the dye does not pass freely in many directions out of the grooves of the catheter, but rather stays near the catheter and exits from the ends of the intraperitoneal limbs. Laparoscopic removal of adhesions from around the catheter can often result in a perfectly functioning PD catheter.

There are two major challenges remaining for all transcutaneous catheters: to diminish infection of the catheter and the surrounding biofilm and to avoid outflow failure due to adhesions. A variety of antibacterial coatings have been developed for central venous catheters, but these coatings have not demonstrated a lower infection rate. To prevent exit site infection and catheter seeding that results in persistent peritonitis, antibacterial materials must be applied to the inside and outside of the peritoneal catheter. In long-term use, silver and sulfon compounds tend to disappear from the surface of the catheters, diminishing effectiveness. Impregnation of the catheter with silver can also cause local irritation of

Fig. 6. Life table analysis of survival of the Advantage PD catheter placed in patients with previous Tenckhoff catheter failures and in patients new to PD.
the exit site and simulate peritonitis. Peritoneal catheters with a long-term and effective antibacterial surface are still an elusive goal, but several new approaches to sterilization or biofilm are now being evaluated. A final challenge is to limit the growth of adventitial tissue around and onto catheters, such as in fibrous sheathing of central venous catheters and omental attachment to peritoneal catheters. Some new materials are being evaluated that are both bactericidal and mildly cytocidal to determine whether these can prevent fibrous attachment and sterilize catheter surfaces and biofilm. These materials must be applied to the catheter body and not the cuffs, so that tissue ingrowth can occur normally to the cuffs while the catheter body avoids such ingrowth.

New Placement Techniques

Several recent publications have described the use of laparoscopic techniques for the placement of peritoneal catheters. These techniques use 5–10 mm diameter trocars generally used for laparoscopic surgery. These are much larger than the 2.2 mm peritoneoscope used in the Y-TEC system, and provide much better visualization of the peritoneal space. However, there are several disadvantages to laparoscopic placement: the procedure usually requires general anesthesia, the CO₂ used to inflate the abdomen is more irritating to the peritoneum than air, the procedure usually requires two punctures to the peritoneum (one for the scope and one for the catheter), and placement of the deep cuff is not automatically ensured to be within the rectus. If the catheter is advanced through a 5 mm split sheath, the deep cuff will be outside the external rectus sheath. If the catheter is advanced through a 10 mm cannula, the deep cuff will end up within the intraperitoneal space or outside the rectus muscle. Some adjustment of cuff position is almost always necessary after the catheter is first placed. As opposed to catheters placed with specially designed equipment, those placed by the laparoscopic technique have no advantage in longevity over those placed by dissection.

Burying the PD Catheter

Traditional surgical implantation of Tenckhoff catheters involves immediate exteriorization of the external segment through the skin, so that the catheter can be used for supportive PD or for intermittent infusions during the “break-in” period. In order to prevent blockage and to confirm function, the catheter is flushed weekly with saline or dialysate; each exchange carries the same risk of peritonitis as in CAPD therapy. The catheter must also be bandaged and the skin exit site must be kept clean in the weeks after placement to avoid bacterial contamination of the exit site. The patient must therefore be trained in some techniques of catheter care. It has always been difficult to decide when to place a PD catheter in a patient with chronic renal insufficiency. If the catheter is placed too early, the patient may spend weeks to months caring for a catheter that is not used for dialysis. If the catheter is placed after the patient becomes uremic, then it is often used for PD therapy without a “break-in” period.

Moncrief et al. (16) devised a placement technique in which the entire peritoneal catheter can be buried under the skin some weeks to months before it is used. The catheter burying technique was first described for placement of a modified Tenckhoff catheter with a 2.5 cm long superficial cuff, but the technique has been adopted for standard dual-cuff Tenckhoff catheters (17–19). In the original technique the external portion of the catheter was brought through a 2–3 cm skin exit site (much larger than the usual 0.5 cm incision). The catheter was tied off with silk suture, then coiled and placed into a “pouch” created under the skin. The skin exit site was then closed. Weeks to months later, the original skin exit site was opened and the free end of the catheter was brought through the original skin exit site (16,17).

The goal of burying the PD catheter was to allow ingrowth of tissue into the cuffs of the catheter without the chance of bacterial colonization, and to create a transcutaneous exit site after tissue had fully grown into the deep and subcutaneous cuffs. Burying the catheter effectively eliminated early pericatheter leaks and decreased the incidence of peritonitis. In 66 months of follow-up, patients with the buried Tenckhoff catheter had peritonitis infection rates of 0.017–0.37 infections per year, versus 1.3–1.9 infections per year in control patients (16). In a study of 26 buried Tenckhoff catheters, the incidence of infections during PD was 0.8 infections/year and the incidence of catheter-related peritonitis was only 0.036/patient-year (17). A retrospective study confirmed significantly lower catheter infection and peritonitis rates in patients with buried catheters and a significantly longer catheter life (20), although the procedure was not effective when used for single-cuff catheters (21).

Exit site infections were not decreased with buried catheters, but this is understandable, since a large exit site is created when the catheter is buried, and a similarly large site is re-created when the catheter is exteriorized (22,23). Creating the “pouch” under the skin requires a considerable amount of dissection and trauma near the exit site. The size of the pocket limits the length of the catheter that can be coiled and buried under the skin, limiting the external length of the catheter after exteriorization. The exit site must be opened widely to remove the catheter, because the coil rests in a position distant from the skin exit site. Subcutaneous adhesions to the silk sutures around the catheter further restricts removal. Increased trauma near the exit site during placement and removal of the catheter have caused an increased incidence of early exit infection with this technique (1–4). In one study of “embedded” catheters in 26 adult patients (with mean subcutaneous residence of 79.5 days), 2 patients developed local seromas and 12 developed subcutaneous hematomas (5 of which were revised surgically) (7). At catheter “activation” there were a number of flow problems; nine patients developed fibrin thrombi (two requiring operative clearance) and four patients had omental catheter obstruction (four requiring omentectomy). When burying the Tenckhoff catheter by standard techniques, there were a total of
27 complications in 26 catheter placements, with 13 of these complications requiring corrective surgery.

When catheters are placed by the Y-Tec procedure, the Quill and cannula of the system can be reassembled and used to bury the external portions of dual-cuff Tenckhoff and Advantage catheters. The catheter exit site is made slightly larger than the standard exit site. The Quill and cannula are inserted through this exit site to create a long, straight tunnel for the external end of the catheter. The catheter is blocked with an internal plug rather than an external silk suture. Using this technique, we have buried and then removed more than 40 Tenckhoff and Advantage catheters. There have been few early complications of hematoma, seroma, exit infection, or outflow failure, and all catheters have functioned after exteriorization.

The first portion of the Y-Tec placement procedure is exactly as usual for a dual-cuff Tenckhoff catheter (9,10,12,13). The only difference is that the skin exit site is chosen slightly more distal from the subcutaneous cuff than usual and the exit site incision is made slightly larger (1 cm, or two widths of the no. 11 scalpel blade rather than the usual 0.5 cm stab wound). After the catheter is tunneled and exteriorized through the exit site, the steps for burying the catheter are as follows:

1. Reattach the Quill guide to the cannula, first inserting the trocar to “lock” the tab into place and then “clicking” the body of the Quill over the cannula (Fig. 7A).
2. Lay the Quill guide and cannula over the skin, in the proper direction just below the umbilicus (for laterally placed catheters), then cut the catheter so that the free end of the catheter reaches the end of the Quill guide (Fig. 7B).
3. Inject 10 ml of sterile saline with 1000 U of heparin into the catheter, then insert the “bullet” end of the Tunnelor tool and break off the tip by rotating the tool backwards and forwards. Advance the outer end of the bullet into the catheter a few millimeters using hemostats (Fig. 7C).
4. Insert the Quill/trocar assembly into the skin just next to the catheter, at an angle to reach the middle of the subcutaneous space (Fig. 7D).
5. Advance the Quill in a direction parallel to the skin surface, directing it into the subcutaneous space just below the umbilicus. Keep the tip of the Quill in the middle of the subcutaneous tissue, between the musculature and the skin. If pain develops, redirect the Quill to avoid the muscle layer, the dermis, or fibrous adhesions (Fig. 7E).
6. Remove the trocar and cannula from the Quill and grasp the tab of the Quill with a hemostat. Dilate the Quill with the small dilator, then the larger 6 mm dilator (Fig. 7F).
7. Gently grasp the catheter with nontoothed forceps or a hemostat and advance the free end of the catheter into the Quill guide (Fig. 7G).
8. Continue to advance the catheter into the Quill guide until the bend of the catheter reaches the skin level. Then hold the bend of the catheter under the skin with forceps and withdraw the Quill guide from around the catheter (Fig. 7H).
9. Close the skin exit site with an absorbable suture; point the needle tip upward, away from the catheter, when advancing it through the subcutaneous tissue (Fig. 7I).

To exteriorize the catheter some weeks to months later, our current technique is the following:

1. Anesthetize the original skin exit site, taking care not to inject too deeply (raise the edges of the incision with toothed forceps, if necessary).
2. Open the original skin incision using mosquito hemostats (if less than 2 months have passed since placement) or a scalpel (if more than 2 months of healing). Using larger hemostats, spread the exit site and subcutaneous tissue to the original 1 cm width.
3. Using a hemostat, probe the wound to find the catheter in its tunnel.
4. Spread the tissue parallel to the tunnel, freeing the tunnel from the subcutaneous tissue along its medial and lateral borders.
5. Advance the tip of the hemostat under the tunnel and lift the tunnel and catheter until at skin level.
6. If the tunnel is very thin and wispy, break it open by grabbing with toothed forceps and pulling portions off the catheter. If the tunnel is thick and substantial, grasp it with small-toothed forceps and cut the grasped portion just below the forceps with Metzenbaum scissors.
7. Advance one jaw of a smooth-tipped forceps under the catheter, grasp and lift the catheter, and pull it through the skin exit site. Hold the outside portion with your fingers, grab the tunneled portion, and pull out a portion. Repeat until the tunneled portion is completely removed.
8. By pressing on the sides of the catheter, express the plug outward and remove it.
9. Attach a suitable long-term connector to the end of the catheter, inject 50 ml of sterile saline, and check for free outflow of fluid and a change in the air-fluid level with respiration, indicating that it is completely open.
10. Do not close the exit site with sutures. Apply a bandage and nonocclusive dressing over the catheter exit site as is done for chronic catheter care in CAPD.

Our technique for exteriorization of the first 20 catheters included a method for creating a tighter exit site near the original exit site. The catheter was exteriorized through the original exit site just as above. Using a scalpел, a stab wound (0.5 cm) was made through the skin just 1 cm lateral to the original exit site. Hemostats were advanced through the new exit site, under the skin and through the original exit site. The tip of the external portion of the catheter was grasped with the hemostats and brought back under the skin and through the new exit site. The original skin exit site was closed with subcutaneous sutures.

We have buried dual-cuff Tenckhoff and Advantage catheters after placement since 1993. Patients selected for this type of placement were those with a trend of renal function that indicated a need for PD in 1–6 months, and we placed peritoneal catheters when the PD therapy was...
anticipated, rather than when it was immediately necessary. The first 30 catheters placed by this technique were studied, with time from placement to exteriorization being 1 week to 1 year. On exteriorization, all of the buried catheters were immediately used for PD, and no patient required HD while awaiting tissue ingrowth to the catheter cuffs or resolution of problems with the PD catheter. Follow-up analysis of these catheters ranged from 3 to 12 months.

Previous publications regarding burying of PD catheters have indicated a number of minor complications following the procedure. Complications seen with these 30 catheters are shown in Table 2.

Long-term peritonitis rates for these patients have been compared to those of patients with catheters exteriorized immediately on implantation. Peritonitis rates are lower for patients with buried catheters, though not statistically different from patients with immediately exteriorized catheters.

In planning for HD of patients with end-stage renal disease (ESRD), it is common practice to place a fistula or graft several months before the need for initiation of dialysis, so that they can “mature” before use. PD catheters also “mature” after placement, with fibrous tissue ingrowth into the cuffs and development of a fibrous tunnel. The fully ingrown catheter is more

Fig. 7. (A–I) Steps for “burying” the external portion of a PD catheter after bringing the external portion through the skin exit site, using the Cannula and Quill components of the Y-Tec system for placement of PD catheters.
resistant to infection of cuffs and the surface of the catheter. The technique of burying PD catheters after placement allows this maturation to occur before use of the catheter, much as with fistulas and grafts. It also allows the time of catheter insertion to be separated from the time of use, without requiring the patient to learn how to care for the catheter site or observe the catheter site for potential complications. At initiation of dialysis, the patient and physician can focus attention on the proper performance of the technique and patient response rather than on function of the catheter. The patient can be trained in full-volume CAPD techniques rather than in “break-in” or cycler techniques used for immediately exteriorized catheters.

A curious aspect of the burying technique is that it seems contrary to “the rules” of catheter break-in. In immediately exteriorized catheters, it is necessary to infuse and drain dialysate or saline (with or without heparin) at least weekly to prevent outflow failure or obstruction of the catheter. However, with the completely buried catheter, there is no infusion of any fluid for periods up to 1 year. Why is this possible? It may be that in the exteriorized catheter, stress and strain on the catheter allows some fluid to enter and exit the side holes during patient movement. The buried catheter has less motion, and with a secure blockage, there is very little fluid inflow/outflow through the holes during normal activity.

Further, the infusion of saline or dialysate during break-in adds a bioincompatible fluid to the abdomen at a time before the catheter is “biolized” or protein/lipid coated. The catheter becomes biolized in the absence of dialysate or saline in the peritoneum. When PD is begun, the catheter is already biolized and less likely to develop omental attachment, even in patients with active omentum. Studies of catheters buried after surgical placement have still shown some early loss due to outflow failure, but the rates are not higher than in immediately exteriorized catheters (7,8). In our study, the peritoneoscopic technique was used for placement of the intraperitoneal portion of the catheter. This method places the catheter against the parietal peritoneum in an area free of adhesions or bowel loops, and this method for placement has already shown a very low incidence of outflow failure on immediately exteriorized catheters. Outflow failure is not increased in incidence by burying the catheter for weeks to months.

### Removing Chronic PD Catheters

In general, if a physician places a device, the same physician is expected to be responsible for following the operation of the device and for removing it when complications require removal or when it is no longer needed. Therefore nephrologists placing peritoneal catheters should also learn to remove them. The techniques of removal are summarized elsewhere (5). For catheters in place less than 1 month or those with infection of the deep or superficial cuffs, the original incision can often be opened by a combination of sharp and blunt dissection. The tunnel may be less well formed and easier to enter. Removal of the cuffs can usually be done with blunt dissection (separating the deep cuff from the surrounding muscle or subcutaneous fibrous tissue with hemostats).

For catheters in place more than 1 month, sharp dissection is necessary to free the cuff and cut the reflecting peritoneal surface (using Metzenbaum scissors and occasionally a scalpel). All Tenckhoff-type and Advantage catheters can be removed without significant discomfort using only local anesthesia, though Toronto-Western catheters require more dissection and may require conscious sedation. The procedure should be done only with sterile technique, good lighting, antiseptic skin preparation (including the catheter near the skin), and draping typical of a procedure done in a surgical suite or outpatient surgery room (drape to cover the primary incision and purposefully exclude the exit site, since the site and catheter, even when treated with antiseptic, cannot be considered clean). Exposure of the deep cuff area is required, so vicryl purse-string sutures can be placed to close the external rectus sheath after removal of the deep cuff and bleeding vessels can be visualized within fibrous tissue. Suction and cautery should be ready for use if needed.

The steps for removing a dual-cuff Tenckhoff or Advantage catheter with solid ingrowth of fibrous tissue to the cuff are as follows:

1. Anesthetize the original primary incision (over the deep cuff).
2. Using a scalpel, make an incision through the primary incision, but extend it on each end so that the incision is about as long as the subcutaneous fat layer is deep (determined by ultrasound before the procedure or by physical examination).
3. Dissect down through subcutaneous fat and occasional fibrous bands to identify the subcutaneous tunnel, then use blunt dissection to separate one portion of the tunnel from the surrounding tissue.
4. Place hemostats under the tunnel and lift the tunnel to the skin surface, securing the tunnel at the skin surface by advancing the hemostats across the incision.
5. Using toothed forceps and Metzenbaum scissors, lift and cut the tunnel layers, eventually exposing the catheter.
6. Clamp the catheter with hemostats, place a nylon suture through the catheter just outside the hemostats (as a tag), then cut the catheter just outside the hemostats.  
7. Lift the deep portion of the catheter with hemostats, grab one edge of the remaining tunnel with toothed forceps, and cut it longitudinally with Metzenbaum scissors. Repeat this step until the scissors reach the level of the outside of the deep cuff.  
8. Anesthetize the rectus sheath and muscle at four points around the deep cuff, then use Metzenbaum scissors to cut the fibrous adherent tissue from the deep cuff (keeping the cuts parallel to and as close as possible to the cuff, and upward tension on the catheter). Observe each cut fibrous layer for any bleeding.  
9. When the lower edge of the cuff is visible or palpable with the tip of the Metzenbaum scissors, the reflected parietal peritoneal surface will be seen surrounding the inner part of the catheter. Cut one side of the parietal peritoneal surface with a scalpel, then extend the incision about halfway around the catheter, ensuring that the catheter itself is partly visible.  
10. Place a two-point wide vicryl purse-string suture around the deep cuff, starting with the point of the curved needle pointing horizontal and pushing the needle down to the external rectus sheath while still placing traction on the catheter. Do not tie the free ends of the suture.  
11. Cut the remaining parietal peritoneal surface free, making sure not to cut the suture, and then remove the internal portion of the catheter while grasping the body with a gauze (to prevent a coiled Tenckhoff catheter) from “flipping” PD fluid when it is free). For Advantage catheters, merely grasp the deep cuff and pull upward.  
12. Tie the vicryl suture snugly into a purse string and cut the needle from the suture. Lift the free ends of the purse string, and place another two-point purse string of vicryl. Cut both purse-string sutures near the knots.  
13. Lift an edge of one of the drapes and cut the catheter at the exit site with scissors (do not use these scissors again in the procedure as they may be contaminated at the exit site).  
14. Pull the nylon tag to expose the cut surface of the outer catheter segment within the primary incision and grasp the catheter segment with hemostats.  
15. Apply traction to the catheter segment, grasp the remaining portion of the subcutaneous tunnel with toothed forceps, and cut the tunnel longitudinally with Metzenbaum scissors. Continue to cut the tunnel and apply traction until the scissors meet the medial portion of the superficial cuff.  
16. Use Metzenbaum scissors to cut connecting fibrous tissue from the cuff, keeping the cuts as close as possible and parallel to the cuff. Observe cut fibrous tissue for signs of bleeding.  
17. When the outer portion of the cuff is felt or is visible, it will be attached to the reflected skin exit site tunnel. Cut one portion of the tunnel and use Metzenbaum scissors to circumferentially cut the rest of the tunnel, freeing the cuff and catheter segment.  
18. Close the primary incision with subcutaneous vicryl, then with nylon skin sutures. Do not close the exit site; if there is bleeding or infection in the subcutaneous space, the catheter tract serves as an effective drainage route.  

Removal of Missouri or Toronto-Western-type catheters is a little more complicated, since the Dacron disc rests next to the peritoneum and develops fibrous adhesion to the peritoneum and the posterior rectus sheath. These catheters are generally placed by surgeons and should be removed by the same surgeons that placed them (5).

References

Due to a production error, the legends for figures 1 and 2 were transposed. The Publisher regrets the error. The following are the corrected figures and accompanying legends.

**Fig. 1.** Distribution of ambulatory systolic and diastolic hypertension in chronic HD patients. Only 3% of the patients had isolated diastolic hypertension. The major burden of hypertension in HD patients is systolic. (Agarwal R, Lewis RR. *Kidney Int* 60:1982–1989, 2001.)

**Fig. 2.** Mortality and cardiovascular morbidity in trials of isolated systolic hypertension treated with dihydropyridine calcium channel blockers (in Syst-Eur and Syst-China trial) or diuretics (in European Working Party on High Blood Pressure in the Elderly Trial). Data are adjusted for sex, age, previous cardiovascular complications, smoking, and active treatment. Pulse pressure analyses are adjusted for mean arterial pressure and mean arterial pressure analyses are adjusted for pulse pressure. Data demonstrate the predictive value of pulse pressure, but not mean arterial pressure, in predicting cardiovascular endpoints in elderly patients. (Data adapted from Blacher J, et al. *Arch Intern Med* 160:1085–1089, 2000.)