**Reviews and Original Articles**

## PERITONEAL CATHETERS AND EXIT-SITE PRACTICES TOWARD OPTIMUM PERITONEAL ACCESS: 1998 UPDATE (Official Report from the International Society for Peritoneal Dialysis)

Ram Gokal,[1] Steven Alexander,[2] Stephen Ash,[3] Tzen W. Chen,[4] Anders Danielson,[5] Cliff Holmes,[6] Preben Joffe,[7] Jack Moncrief,[8] Kirt Nichols,[9] Beth Piraino,[10] Barbara Prowant,[9] Alain Slingeneyer,[11] Bernd Stegmayr,[12] Zbylut Twardowski,[9] Stephen Vas[13]

*Manchester Royal Infirmary,[1] Manchester, U.K.; Stanford University Medical Centre,[2] Stanford, HemoCleanse,[3] West Lafayette, Indiana, U.S.A.; Veterans General Hospital,[4] Taipei, Taiwan; Karolinska Institute,[5] Huddinge, Sweden; Baxter Healthcare,[6] McGaw Park, Illinois, U.S.A.; Holbæck County Hospital,[7] Holbæck, Denmark; Moncrief Dialysis Center,[8] Austin, Texas, University of Missouri,[9] Columbia, Missouri; University of Pittsburgh Medical Centre,[10] Pittsburgh, Pennsylvania, U.S.A.; Hôôpital Lapeyronie,[11] Montpellier, France; University Hospital,[12] Umeåå, Sweden; Toronto Western Hospital,[13] Toronto, Ontario, Canada*

**The key to successful chronic peritoneal dialysis**

(PD) is permanent and safe access to the peritoneal cavity. Despite improvements in catheter survival over the last few years, catheter-related complications still occur, causing significant morbidity and often forcing the removal of the catheter. Catheter-related problems are a cause of permanent transfer to hemodialysis (HD) in up to 20% of all patients who need such therapy changes; many more require temporary periods on HD. Since the incidence of peritonitis is declining following the introduction of new connectology, catheter-related complications during PD have become a major concern.
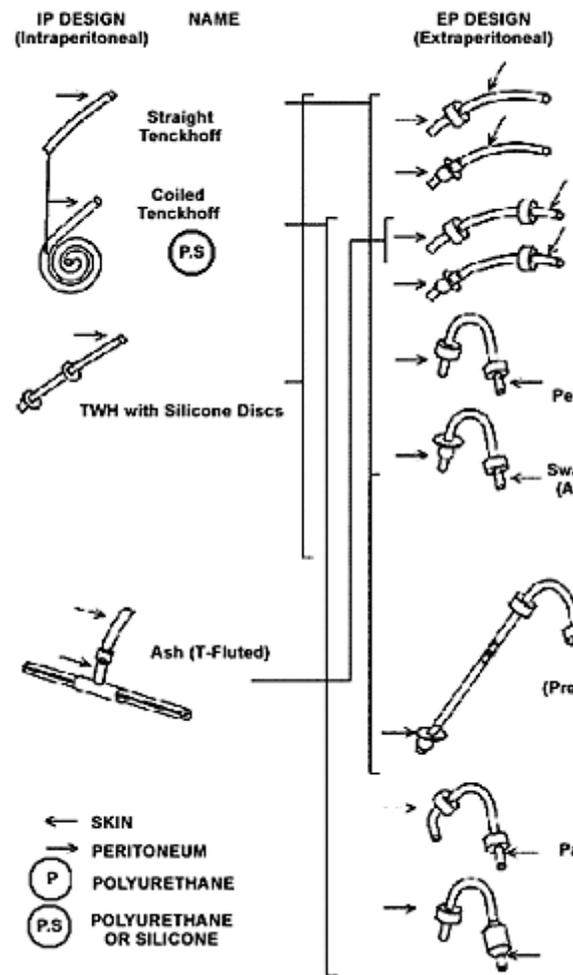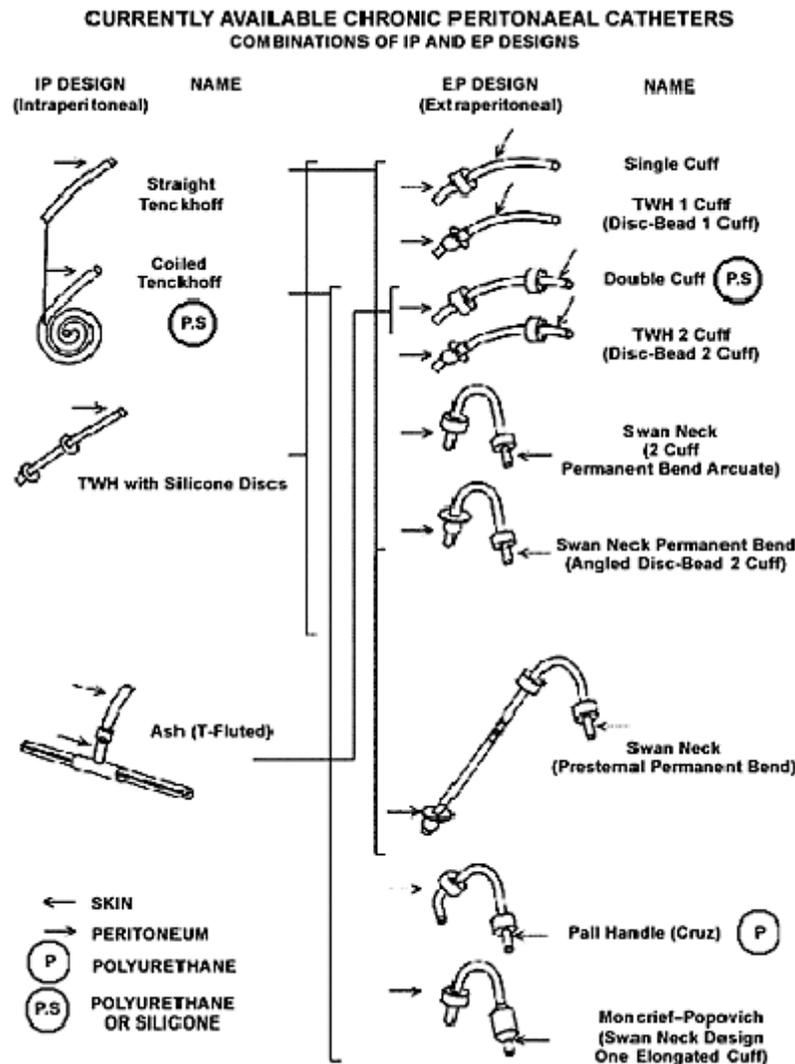
A panel of experts, who are co-authors of this report, recently met to discuss catheter-related problems with a view to establishing guidelines toward optimal peritoneal access. Some of the members of this group also participated in previous reports (Oreopoulos in 1987; Gokal *et al.* in 1993). Wherever possible, the guidelines are evidence-based (e.g., randomized controlled trials); where scientific evidence is not available, recommendations are based on a consensus opinion. It is our hope that these guidelines for peritoneal catheter management will help to improve catheter care and, therefore, patient outcomes. An Appendix gives guidelines for pediatric catheter practices where they differ from the adult practices.

## PERITONEAL CATHETERS

The ideal catheter provides reliable, rapid dialysate flow rates without leaks or infections. Despite many newer catheter designs, the Tenckhoff catheter is still most often used (USRDS 1992; Lupo *et al.*, 1994). Variations of the peritoneal catheter include the number of cuffs (one versus two), the design of the subcutaneous pathway (permanently bent vs straight), and the intra-abdominal portion (straight vs coiled).

**Types of Catheters (Figures 1 and 2)**

**CURRENTLY AVAILABLE CHRONIC PERITONEAL CATHETERS**
**COMBINATIONS OF IP AND EP DESIGNS**

IP DESIGN     NAME
(Intraperitoneal)

EP DESIGN     NAME
(Extraperitoneal)

Straight Tenckhoff

Coiled Tenckhoff (P.S)

TWH with Silicone Discs

Ash (T-Fluted)

Single Cuff

TWH 1 Cuff
(Disc-Bead 1 Cuff)

Double Cuff (P.S)

TWH 2 Cuff
(Disc-Bead 2 Cuff)

Swan Neck
(2 Cuff
Permanent Bend Arcuate)

Swan Neck Permanent Bend
(Angled Disc-Bead 2 Cuff)

Swan Neck
(Presternal Permanent Bend)

Pail Handle (Cruz) (P)

Moncrief-Popovich
(Swan Neck Design
One Elongated Cuff)

← SKIN
→ PERITONEUM
(P) POLYURETHANE
(P.S) POLYURETHANE OR SILICONE

← SKIN
→ PERITONEUM
(P) POLYURETHANE
(P.S) POLYURETHANE OR SILICONE

The chronic peritoneal catheter comprises an intra- and an extraperitoneal portion; the latter consists of a subcutaneous part that has a means to anchor the catheter (e.g., cuffs), and the external portion beyond the exit site (the latter is the same for all catheters). The standard, two-cuff, straight Tenckhoff catheter is still the most widely used access device, because it satisfies the needs of most patients and there is no conclusive evidence that any other catheter is superior (USRDS 1992; Piraino, 1995; Lupo et al., 1994). There are, however, many catheter variations designed to minimize complications of pain, inadequate flow, and infections (Figures 1 and 2). Catheters that are commonly used to gain peritoneal access are shown in Figure 1. These are the standard one- or two-cuff, straight or coiled Tenckhoff

catheters, the Swan neck catheters, and the Toronto—Western Hospital (TWH) catheter. Figure 2 shows the currently available chronic catheters, illustrating the intraperitoneal (IP) and extraperitoneal (EP) designs. It is possible to combine EP and IP designs as shown.

**Intraperitoneal Segment —— for Improving Outflow:** The catheter should always allow easy inflow and outflow of fluid; the latter can be more variable and difficult, especially during the last part of drainage.

**Straight:** The straight catheter, which can be utilized in combination with almost all extraperitoneal designs (Figure 2), is the most common design and the one that was originally used when the catheter was introduced in the 1960s by Tenckhoff. It comprises side holes to enhance flow in and out of the peritoneal cavity.

**Coiled:** The coiled catheter design, which can be utilized in combination with most extraperitoneal designs (Figure 2), provides an increased bulk of tubing to separate the parietal and visceral layers of the peritoneum. Flow in and out of the tip of the catheter is more protected and there are more side holes for outflow. It is believed that this design allows for better flow, less inflow pain, less propensity for catheter migration and omental wrapping, and is less traumatic to viscera than the tip of a straight catheter; however, conclusive evidence for this is lacking.

**Silicone Discs:** Silicone discs perpendicular to the catheter (as in the TWH catheter, Figures 1 and 2) hold the omentum and bowel away from the exit holes. These are also designed to maintain their position in the pelvis and thus minimize catheter tip migration. Disadvantages include more difficult surgical implantation and removal than standard Tenckhoff catheters.

**T-Fluted:** This design is shaped like a ""T."" The intraperitoneal portion lies against the parietal peritoneum. Instead of side holes, the intraperitoneal portion has eight, 1 mm wide longitudinal ""flutes"" or grooves. This design allows better flow and prevents migration (Ash and Janle, 1993).

**Subcutaneous Tract: Straight:** This original design has been used with single- or double-cuff catheters or the beaded TWH catheter. The subcutaneous segment may be implanted in an arcuate tunnel, to enable the catheter exit to be caudally or laterally directed. Implantation of the straight catheter in an arcuate tunnel may increase catheter tip migration or external cuff extrusion as the catheter tends to ""straighten"" because of its resilience or ""shape memory""; however, good results with straight catheters can be achieved (Favazza et al., 1995).

**Permanent Bend:** This design has a preformed bend, eliminating the resilience force or ""shape memory"" of straight catheters. It must be implanted in a tunnel that exactly reflects this shape. There are several varieties available:

> 1. The Swan neck catheter. Investigators at the University of Missouri (Twardowski et al, 1992) have advocated catheters with an inverted U-shaped arc (170 — 180 degrees) between the deep and superficial cuffs. The U-shaped, (arcuate) bend allows the catheter to exit the skin pointing downward and yet enter the peritoneum pointing toward the pelvis, in an unstressed condition as Tenckhoff originally suggested. The bead-and-disc cuff is incorporated into the design. The Swan neck Tenckhoff differs from the double-cuff Tenckhoff only by the 170 — 180 degree bend between the cuffs. 2. The Moncrief—Popovich catheter (Moncrief et al., 1996). This catheter is very similar to the standard Swan neck Tenckhoff catheter except that the external skin cuff is elongated to 2.5 cm and is tapered at the ends of the cuff.3. The Swan neck Missouri (see below). 4. Pail-

handle (Cruz) catheter (Cruz, 1992). This catheter has two right-angle bends: one to direct the intraperitoneal portion parallel to the parietal peritoneum, and one to direct the subcutaneous portion downward toward the skin exit site. The cuffs are small, permitting peritoneoscopic insertion. The catheter is available only in polyurethane. The clinical benefits of this catheter include more rapid inflow and outflow than standard silicone catheters because of the larger inner diameter. 5. Swan neck presternal catheter. This catheter is a modified Swan neck Missouri coil catheter. The major difference from the standard Swan neck Missouri catheter is in the length of the subcutaneous tunnel. The catheter is composed of two silicone rubber tubes that are to be connected end-to-end at the time of implantation (Twardowski et al., 1996). The implanted lower (abdominal) tube constitutes the intraperitoneal catheter segment and a part of the intramural segment. The upper, or chest, tube constitutes the remaining part of the intramural segment and the external catheter segment. This upper part has two cuffs, one on either side of the bent segment. This catheter is useful in extremely obese patients and those with ostomies (Twardowski et al. 1996).

**Outcome in Relation to Exit Direction:** A downward-directed exit site was associated with lower peritonitis rates in a report from pediatric centers in North America (Warady et al., 1996). In addition, the Network 9 study found that directing the subcutaneous portion of the catheter downward decreased the risk of peritonitis associated with exit-site and/or tunnel infection by 38%, while an upward-directed catheter had a 50% increased risk of catheter-related peritonitis, compared to horizontally-directed tunnels (Golper et al., 1996). The United States Renal Data System (USRDS) reported that the relative risk of peritonitis was essentially identical for straight and bent catheters; however, when the analysis was repeated with adjustment for possible center effect, the peritonitis rate was significantly lower with permanent bent catheters.

Swan neck catheters were designed to diminish cuff extrusions and catheter-tip migration associated with straight catheters implanted in arcuate tunnels. Although several studies have shown no advantage of bent catheters over straight catheters (Nebel et al., 1991; Bonzel et al., 1993), other studies have shown significantly better results (Hwang and Huang, 1994; Tielens et al., 1993). Randomized studies comparing a Swan neck catheter to the straight Tenckhoff catheter without a preformed bend showed a lower probability for a first exit infection with the Swan neck catheter, but the survival was not different (Eklund et al., 1994; Eklund et al., 1995). Cuff extrusions and catheter migration were seen only in the Tenckhoff catheters. In another randomized study, there was a significantly lower rate of exit-site infections with Swan neck catheters (Lye et al., 1996).

**Anchorage: Dacron Cuffs:** These are either one or two in number and are made of polyester fiber. The usual distance between the two cuffs is 5 cms. For obese patients this may be inappropriately short. A single cuff can function (flow and stability) as well as a double cuff when the single cuff is in the deep position.

**The Bead-and-Flange at the Deep Cuff:** This feature is utilized to strengthen the anchorage of the catheter into the abdominal wall. During implantation, the ball is located intraperitoneally and the flange is positioned flat above the peritoneum on the posterior rectus sheath. A purse-string suture between the bead and the flange decreases the risk of early leakage. The flange increases the mass of tissue ingrowth into the cuff/flange structure, which decreases the risk of leakage.

1. The TWH catheter has the flange and bead affixed perpendicular to the tubing. 2. The Swan neck Missouri catheter has the bead and flange affixed to the tubing at a 45 degree angle, so that, with placement, the intraperitoneal part naturally tends to angle downwards with less tendency to migrate into the upper abdomen. The slanted flange-and-bead, and bent tunnel segment require that the Swan neck Missouri catheters for right and left tunnels be mirror images of each other. A radiopaque stripe on the front of the catheter facilitates recognition of the right and left Missouri catheters and proper implantation.

**Outcome in Relation to Number of Cuffs:** The single-cuff catheter is associated with a shorter time to the first peritonitis episode (USRDS 1992; Warady et al., 1996; Honda et al., 1996). In addition, the single-cuff catheter (Lindblad et al., 1988; Favazza et al., 1995) has more exit-site complications and shorter survival times than the double-cuff catheter. Therefore, convincing data exist to indicate that double-cuff rather than single-cuff catheters should be used for chronic PD.

**Catheter Materials**

**Silicone:** The most frequently used material for permanent catheters over the last 30 years has been smooth silicone rubber (Silastic). The standard PD catheter is still made of silicone rubber and provided with up to two polyester cuffs. The silicone rubber is a polymer of methyl-silicate, the higher molecular weights being gums from which silicone rubber is made. The biocompatibility of silicone rubber is satisfactory because it is inert, atraumatic to the surrounding tissues, soft, flexible through a wide range of temperatures, and contains no clinically harmful, leachable plasticizers.

**Polyurethane:** To overcome the problem of catheter wall strength, polyurethane has been used. This has allowed thinner-walled catheters with larger lumens, thus allowing for quicker flows. It is also more pliable with increasing temperature. There does appear to be hydrolysis of the polyurethane surface and there have been reports of cracking of the material with constant use, especially when polyethylene glycol or alcohol is applied. The experiences of only one center are available (Cruz, 1992).


**CATHETER CHOICE AND CATHETER OUTCOMES**

A Network 9 study (Golper et al., 1996) reported the outcome of 1930 catheters used between 1991 and 1993. Overall, 1- and 2-year catheter survivals were 82% and 70%, respectively. Peritoneal dialysis-related infections, including peritonitis, catheter-related peritonitis, and catheter infection, account for 75% or more of the catheters lost (Golper et al., 1996; Eklund, 1995; Weber et al., 1993). In the Network 9 study, mechanical problems such as dialysate leaks (3%) and drainage failure (4%) were less common causes of catheter loss than reasons involving infections.

**Outcome Studies**

**These are summarized as follows:**

**Randomized Studies:** Table 1 summarizes outcomes in randomized trials with various catheter designs and placement techniques.

**Other Outcome Analyses:** An extensive overview of outcomes in terms of complication rates (infection, obstruction, and leaks) by type of catheter and placement technique has been published and shows variable results (Ash and Nichols, 1994).

## RECOMMENDATIONS

1. Catheter survival of >80% at 1 year is a reasonable goal. 2. Convincing data exist to indicate that the double-cuff catheter is preferable to the single-cuff catheter, therefore a double-cuff configuration is advocated. 3. A downward-directed exit may decrease the risk of catheter-related peritonitis. Properly implanted, preformed arcuate or pail-handle catheters, will always have a downward-directed exit and are, therefore, advantageous in this respect. 4. Overall, no catheter appears to be superior to the original 2-cuff, standard Tenckhoff catheter, although experience with Swan neck catheters is promising; there is a need for large, randomized prospective studies and long-term experience.

**Table 1**

Randomized Controlled Studies on Catheter Outcome

| Study | Catheter | Outcome | | Significance |
|-------|----------|---------|---|------------|
| Akyol, 1990 | Tenkhoff straight vs coiled, 20 pts | 1-yr Survival: | 90% Straight 70% Coiled | NS |
| Nielson, 1995 | Tenckhoff straight vs coiled, 72 pts | 3-yr Survival: | 78% Straight 40% Coiled | $p < 0.01$ |
| Scott, 1994 | Straight vs coiled vs Toronto-Western, 90 pts | No differences in complications | | NS |
| Eklund, 1994 | Straight vs Swan neck, 40 pts | 2-yr Survival: | 78% | NS |
| Eklund, 1995 | Straight vs Swan neck, 40 pts | 3-yr Survival: | 90% Swan neck 80% Tenckhoff | NS |
| Lye, 1996 | Straight vs Swan neck coiled, 40 pts | 1-yr Survival: | 95% Swan neck 90% Straight | NS |
| | | Swan neck: | less exit-site infection | |

## CATHETER INSERTION

**Ideally, catheter insertion should be undertaken under operating room, sterile conditions. This can be done on either an inpatient or an outpatient basis. Several placement techniques are described and practiced:**

1. Surgical placement by dissection. 2. Blind placement using Tenckhoff trocar. 3. Blind placement using guidewire (Seldinger technique). 4. Minitrocar placement using peritoneoscopy. 5. Other modifications (Moncrief and Popovich, presternal).

**Preimplantation Preparation**

The procedure, including the incidence and nature of complications, should be described to the patient and all questions answered in a reassuring way, allowing a change to HD if not satisfactory.

**Presurgical Assessment:** Presurgical assessment of the patient is essential, searching for herniation, eventration, and weakness of the abdominal wall. If present, it may be possible to correct these at the time of catheter insertion. Peritoneal dialysis should then not start during the first 4 weeks, due to increased risk of leakage.

**Determination of the Exit Site:** Prior to insertion, the exit site should be identified and marked on the skin. This can be done by the operating surgeon, the nephrologist, or an experienced PD nurse. It is advisable to avoid locations where there may be pressure during daily activities.

**The exit site should be:**

1. either above or below the belt line, should not lie on a scar, and should not be in abdominal folds. The umbilicus should not be used as a reference mark; 2. determined with the patient in an upright (seated or standing) position; 3. placed laterally. A stencil can be applied to demarcate the tunnel and exit site clearly (as is the case for the Swan neck catheter insertion).

**Skin Preparation:** On the morning of the operation, the patient should bathe or have a shower with chlorhexidine soap. If necessary, abdominal hair should be clipped. Patient''s nares may be swabbed to determine nasal carriage of Staphylococcus aureus. Eradication of nasal carriage has shown significant improvement in exit-site infections but has a cost implications (Dryden et al., 1991; Mupirocin Study Group, 1996).

**Bowel Preparation:** Bowel preparation and the avoidance of constipation are of paramount importance. Similarly, emptying the bladder before the procedure is mandatory.

**Prophylactic Antibiotics Before Implantation:** There is some recent evidence that prophylactic antibiotics prevent subsequent catheter infections, peritonitis, and wound sepsis (Golper and Tranææus, 1996). In a recent controlled study using cefuroxime (1.5 g, IV 1 — 2 hours preoperatively, and 250 mg intraperitoneally perioperatively), the prophylactic group had fewer peritonitis episodes than controls (Wikdahl et al., 1997). However, other reports differ (Lye et al., 1992). USRDS 1992 data in 3366 patients showed no difference between patients having had antibiotic prophylaxis compared to those who did not (using the Cox proportional hazards method).

Nevertheless, the use of antibiotic prophylaxis during surgical interventions has a large and convincing literature. It usually consists of using an antistaphylococcal antibiotic, given 1 hour pre- and 6 — 12 hours postoperation.

**RECOMMENDATIONS**

1. The experience in general surgical practice indicates that perioperative antibiotics, especially in the presence of a foreign body, diminish the incidence of wound infection. A first-generation cephalosporin has been most frequently used in this context and is advocated especially in centers with high postoperative wound or exit infections. 2. Vancomycin should not be routinely used for perioperative prophylaxis to avoid the development of resistant micro-organisms such as vancomycin-resistant enterococci (VRE) and vancomycin-resistant Staph. aureus.

## Catheter Implantation Techniques

The implantation technique has a significant influence on the complications and outcome of the chronic peritoneal catheter. To achieve good long-term results, implantation must be performed by a competent and experienced catheter insertion team. Inexperienced personnel should not be permitted to perform the implantation except under the direct supervision of an experienced physician or surgeon. There are several areas of general agreement regarding the placement of peritoneal catheter devices.

## RECOMMENDATIONS

1. The implantation must be performed by a competent and experienced operator, in a planned manner. The procedure must be regarded as an important surgical intervention demanding care and attention to detail equal to any other surgical procedure. 2. Peritoneal entry should be lateral (deep cuff in or below the rectus musculature), or paramedian (deep cuff at the medial edge of the rectus muscle), to give good deep-cuff fixation and minimize herniation and fluid leaks. Other entry sites (midline through the linea alba) are used with trocar insertions. 3. The deep cuff should be placed in the musculature of the anterior abdominal wall or in the preperitoneal space. Good results have also been obtained with the cuff placed within the posterior rectus fascia. The deep cuff should never be placed within the peritoneal cavity. After proper positioning of the catheter tip, the peritoneum is closed tightly around the catheter below the level of the deep cuff using a purse-string suture. 4. The subcutaneous cuff should be located near the skin surface and at a distance of at least 2 cm from the exit site. Care should also be taken to avoid mechanically stressing the cuff material. 5. Check for catheter patency. The catheter should be tested to ensure that there is adequate inflow and outflow without leakage. Techniques to accomplish this include infusing 1 L of peritoneal fluid over 5 minutes and allowing an equal time for drainage, or injecting 60 mL of 0.9% saline and observing if 30 — 40 mL is easily aspirated. 6. The exit site should be facing downwards or be directed laterally. Upward-directed exit sites should, in general, be avoided. 7. The intra-abdominal portion of the catheter should be placed between the visceral and parietal peritoneum toward the pouch of Douglas and should not be placed within loops of bowel or directly in omental tissue. This maneuver has been shown to be facilitated by the use of a bent stylet (Stegmayr et al., 1993) or any device that will add rigidity to the catheter.

Surgical Insertion of PD Catheters (Placement by Dissection): Surgical implantation is the most common method for placement of chronic peritoneal catheters. Surgical placement begins with either extensive local anesthesia or light general anesthesia. There are two general approaches: the lateral approach and the paramedian approach. Either can be used with any of the catheters, although TWH and Missouri catheters are usually placed using the paramedian technique. Detailed descriptions of the various techniques can be found elsewhere and are not reproduced here (Ash and Nichols, 1994; Ash and Daugirdas, 1994).

**Blind Insertion Technique (Tenckhoff Trocar):** This procedure should not be done in patients who are extremely obese or where intra-abdominal adhesions may be expected, since the risk of bowel perforations will be increased in such patients. It also is not optimal in patients for whom PD is to start acutely, since there is an increased incidence for early leakage (2% — 43%), outflow failures (5% — 50%), and infectious complications. Normally, the catheter for chronic use is inserted on one occasion and then not used until 2 — 4 weeks later, enabling ingrowth of the cuff and thereby reducing the risk of leakage. If an immediate start is necessary, and supine dialysis is not possible, then this technique is inappropriate. Surgical back-up should be available for complications such as bowel perforation or excessive hemorrhage. The detailed description of the insertion technique has been previously described (Gokal et al., 1993; Ash and Daugirdas, 1994). If the catheter is not used, there is no need for regular flushing to maintain patency or checking for it.

**Blind Placement Using the Seldinger Technique:** This technique is somewhat similar to the split-sheath technique used for subclavian or internal jugular catheters, and is described in detail elsewhere (Ash and Daugirdas, 1994; Ash and Nichols, 1994).

This technique involves passing a guide needle, attached to a syringe with 2 — 3 mL of saline, through the linea alba or the dissected rectus muscle sheath into the peritoneal cavity, with the syringe contents being injected after appreciating the ""give,"" indicating entry into the peritoneal cavity. A Seldinger guide wire is passed through the needle, which is then removed.

A tapered dilator with surrounding scored sheath is passed caudally over the wire, which is in turn removed. The Tenckhoff catheter is then inserted through the guide and the sheath is split to allow the cuff to reach the outer surface of the fascia. With the catheter held in place, the catheter guide is stripped away.

**Use of the Minitrocar and Peritoneoscopy:** The use of the peritoneoscopy for peritoneal catheter placement is now well accepted and details of the insertion technique are described elsewhere (Ash and Nichols, 1994; Ash and Daugirdas, 1994).

**Moncrief—Popovich Technique:** This technique incorporates two modifications of the conventional implantation procedure. The segment that would ordinarily be brought out through the skin in the standard implantation technique, is completely buried under the skin in a subcutaneous tunnel. The entire wound is then closed with no exit site. Healing and tissue ingrowth occurs into the cuffs in a sterile environment. At a subsequent date of convenience, 4 – 6 weeks after insertion, a small incision is made 2 cm distal to the subcutaneous cuff and the distal segment of the catheter is brought out through the skin. The catheter may be left in place under the skin for many months. Peritoneal dialysis may be initiated immediately following exteriorization, without break-in or waiting time. This technique theoretically prevents early bacterial invasion of the tunnel and the cuff material immediately postoperatively, when the wound is fresh and most vulnerable to bacterial invasion into the deep tissues.

**Presternal Catheter Insertion Technique:** This catheter is a modified Swan neck, Missouri coil catheter. The major difference from the Swan neck Missouri catheter is in the length of the subcutaneous tunnel. The catheter is composed of two silicon rubber tubes which are to be connected end-to-end at the time of implantation. Insertion details are described elsewhere (Twardowski et al., 1996).


**IMMEDIATE POSTOPERATIVE CARE**

**The goals of postoperative catheter care are to:**

1. minimize bacterial colonization of the exit and tunnel during the early healing period;
2. prevent trauma to the exit site and traction on the cuffs by immobilization of the catheter; 3. minimize intra-abdominal pressure to prevent leakage.

There are several approaches to postoperative catheter care. However, there is little evidence to support the superiority of one approach over the others. In general terms, it is advisable to minimize catheter movement and handling of the catheter or exit site until healing of the wound and the catheter tract is complete; this is thought to take at least 3 — 4 weeks. There is also risk of fluid leakage if large volumes of dialysate are utilized prematurely, especially if the patient is active when fluid is in the peritoneal cavity; dialysis, if undertaken immediately, needs to utilize small exchange volumes and the patient should be in a supine position.

**Postimplantation Dialysis**

Although immediate dialysis without leakage of fluid is possible, it is preferable to postpone dialysis for 1 — 3 days to permit good tissue healing. It is common to flush the peritoneal cavity hourly with 200 — 1500 mL (most commonly 500 mL) PD solution. Heparin (500 — 1000 U/L) can be added in cases of fibrin or blood clot formation. Once the effluent is clear, the catheter can be safely capped.

If dialysis is required immediately, it should be initiated in the supine or semirecumbent position with reduced exchange volumes (500 — 1500 mL). For patients who will require further dialysis, the volumes should be increased gradually from 500 mL to the maximal desired volume in order to minimize the risk of dialysate leaks.

Depending on the implantation technique, ambulatory PD is usually not initiated for 10 days after catheter insertion; the longer the period of nonuse the better is the healing, with a resultant reduction in complications. During this period, the patient can be maintained with intermittent PD as described above, nighttime cycling, or placed on HD through temporary venous access via central veins. In the case of elective implantation, the patient remains off dialysis until the time for continuous ambulatory peritoneal dialysis (CAPD) training. If the peritoneal catheter is not used, there appears to be no need to check catheter patency and function.

**RECOMMENDATIONS**

1. Flush the catheter with small volumes until the effluent is clear. 2. Commencement of CAPD is dependent upon the implantation technique, but generally the catheter should be capped for at least 2 weeks before initiating CAPD. 3. Peritoneal dialysis in this interim period should be intermittent, using small volumes and with the patient in a supine position. The exchange volumes can be gradually increased.

**Early Exit-Site Care**

The optimal care of the PD catheter exit site after catheter implantation is not known. There is no consensus regarding specific procedures, cleansing agents, dressings, or methods of immobilization, and since there are no controlled studies on which to rely, the recommendations below are based on broad, general principles.

**Dressings:**

1. After implantation, the exit site should be covered with several layers of sterile gauze. Transparent, occlusive dressings should not be used alone because drainage tends to pool

at the exit site and in the sinus. Gauze dressings are more appropriate because they wick the drainage away from the exit. The surgical dressing should not be changed for several days unless there is obvious bleeding or signs of infection. 2. Frequent dressing changes in the immediate postimplantation period are not necessary. The rationale for less frequent dressing changes is based on the risk of contaminating the exit at each dressing change, despite aseptic precautions, and the risk of local trauma from manipulations of the catheter. The dressings should be changed no more than once per week. Once the exit is colonized with bacteria, by week 2 or 3 (Twardowski et al., 1996b), more frequent dressing changes are indicated. 3. It is generally accepted that dressing changes following catheter implantation should be restricted to specially trained staff (Prowant et al., 1993; Lewis et al., 1997). Aseptic technique, using face masks and sterile gloves, is recommended for postimplantation exit-site care (Prowant and Twardowski, 1996). 4. Patients should avoid submerging the exit site during healing to avoid colonization with water-borne organisms. 5. Although sterile dressings are recommended until the exit is well-healed, there is no clear consensus as to when patients may begin to shower or change to chronic exit-site care. The exit-site evaluation and classification developed by Twardowski (see below) may be used for this purpose. When the exit site can be classified as good or equivocal, then showering and chronic care are appropriate.6. In tropical or subtropical areas, sweating may affect the frequency of early dressing changes, which should be done when the exit site is wet, when the patient feels itchy under the taped skin, or when the stickiness of the tape is lost.

**Cleansing Agents or Disinfectants:** Povidone iodine and hydrogen peroxide were recommended by Tenckhoff for cleaning the exit postoperatively and have been used ever since. There is, however, evidence in the surgical literature that wound disinfectants, including hydrogen peroxide and povidone iodine, are cytotoxic, causing tissue damage and delaying clean wound healing (Lineaweaver et al., 1985). If a strong oxidant is used, care should be taken to keep it out of the exit sinus. Alternate cleansing agents such as normal saline, a nonionic surfactant agent (20% polaxamer 188), and pure soap are currently used for postimplantation care (Lewis et al., 1997; Prowant et al., 1993; Prowant and Twardowski, 1996); however, there are no prospective, controlled studies to assess outcomes.

**Immobilization:** The catheter should be immobilized using a dressing or tape. It is advisable to prevent torquing movement and to minimize handling of the catheter until the exit site and tunnel are completely healed; usually this period lasts at least 4 — 6 weeks (Twardowski et al., 1996c). This will reduce the incidence of trauma and promote tissue growth. Although a number of devices for catheter immobilization are available, the only controlled study did not show the immobilizer to be more effective than tape or dressings in preventing exit infection (Turner et al., 1992).

## RECOMMENDATIONS

1. Restrict care to experienced PD staff or trained patients. 2. Use aseptic technique. 3. Avoid irritating or toxic solutions for cleansing; if povidone iodine or hydrogen peroxide are used, keep them out of the sinus or wound. 4. Use absorbent dressings and keep the exit as dry as possible. 5. Continue sterile dressings until the exit is healed. 6. Immobilize the catheter. 7. Infrequent dressings changes (once per week) suffice for the first 2 — 3 weeks.

**CHRONIC CARE OF THE HEALED EXIT SITE**

The primary goal of chronic exit-site care is to prevent exit-site infections. In a broad sense, exit-site care includes assessment of the exit, cleansing the exit, anchoring or immobilizing the catheter, and protecting the exit site and tunnel from trauma (Prowant and Twardowski, 1996).

As with postimplantation care, optimal chronic exit-site procedures for peritoneal catheters are undetermined. The few controlled studies have focused primarily on the cleansing agent used for exit care or on the use of dressings.

The optimal frequency of exit-site care has not been established; however, frequent cleansing is essential to reduce resident bacteria, and daily care is recommended by the vast majority of units. Exit-site care should also be repeated when the exit becomes grossly dirty or wet. Good hand washing prior to exit care is critical to avoid cross contamination.

Assessment of the exit site by visual inspection and palpation of the tunnel should be a routine part of exit-site care for both health care professionals and patients. Initial patient education should include how to assess the exit site, signs and symptoms of exit-site infection, and when to notify the PD unit of exit-site problems.

**Cleansing Agents**

Several studies have compared cleansing agents used in exit-site care. A large, multicenter study found significantly fewer infections when povidone iodine was used in comparison with pure soap (Luzar et al., 1990); another study found similar rates between povidone iodine and soap (Warady et al., 1987), and one study (Prowant et al., 1988) and a quality improvement report (Hasbargen et al., 1993) found higher rates with povidone iodine compared to an antibacterial soap. It is likely that pure soap does not effectively reduce the number of organisms at the exit site, and that use of a cleansing agent with antimicrobial properties is essential. An antibacterial soap may be appropriate. Liquid soap is preferred to avoid the risk of cross contamination from bar soap. Povidone iodine solutions contaminated with Pseudomonas spp have been implicated as the source of both peritonitis and exit-site infection in CAPD patients. To avoid contamination of liquid soaps and disinfectants, they should not be transferred from one container to another.

**RECOMMENDATIONS**

1. Catheter exit sites should be washed daily or every other day with antibacterial soap or a medical antiseptic to keep the exit clean and to diminish resident bacteria. 2. The choice of a soap or cleansing agent may need to be individualized because of skin sensitivities or allergies. 3. It is important not to forcibly remove crusts or scabs during cleansing because this may traumatize the exit, causing a break in the skin and thus increase the risk of exit infection. 4. The exit should be patted dry after cleansing. The use of sterile gauze or cotton-tipped applicators is not necessary for care of the healed exit; a clean wash cloth and towel suffice. 5. Liquid soap and disinfectants should not be transferred to other containers because of the risk of cross-contamination.

**Dressings**

Studies in chronic exit-site care in adults showed a similar incidence of exit infection in groups with and without dressings (Starzomski, 1984; Khanna and Oreopoulos, 1983). Because there are no data to document lower infection rates in adults, the use of dressings for chronic care is based on anecdotal experience or individual preference. Theoretically, the use of dressings may help keep the exit clean, protect it from trauma, and help to stabilize the catheter. Furthermore,

dressings are indicated for all patients when the exit is infected or likely to become grossly contaminated.

Gauze dressings are used most frequently but semipermeable dressings and occlusive dressings are also used. The few studies comparing different types of dressings have found either no differences in infection rates or have conflicting findings.

A retrospective analysis in pediatric patients showed significantly fewer infections in exit sites covered with an occlusive sterile dressing. It may be that this difference is due to the increased risk of gross contamination and trauma to the exit site of infants and children.

**DIAGNOSIS AND TREATMENT OF EXIT-SITE AND TUNNEL INFECTIONS**

A detailed description of the peritoneal catheter tunnel morphology has been published (Twardowski et al., 1991). In addition, a supplement of Peritoneal Dialysis International has been dedicated to this topic (Perit Dial Int, 1996).

Exit-site and tunnel infections are important because they may lead to refractory or relapsing peritonitis and subsequent catheter loss. In the majority of these patients, the catheter must be removed to resolve the infection (Gupta et al., 1996). The risk of peritonitis from a catheter infection varies with the infecting organism. Staphylococcus epidermidis exit-site infections seldom result in tunnel infections, peritonitis, or catheter loss, while exit-site infections due to Staph. aureus and Pseudo. aeruginosa frequently lead to peritonitis and catheter loss.

**Definition and Occurrence**

The site of the infection can be the sinus (exit-site infection) or the subcutaneous or external cuff and tunnel (tunnel infection). The preperitoneal cuff can also be infected but this is difficult to diagnose. Infections can be acute or chronic. Acute infections last for less than 4 weeks while chronic infections are of greater duration.

**Acute Exit-Site Infection:** An acute exit-site infection is defined as purulent and/or bloody drainage from the exit site which may be associated with erythema, tenderness, exuberant granulation tissue, and edema (Twardowski and Prowant, 1996b). The erythema needs to be more than twice the catheter diameter; there is regression of the epithelium in the sinus. An acute catheter infection may be accompanied by pain and the presence of a scab, but crusting alone is not indicative of infection.

Appearance of the infected exit site correlates with catheter outcome (Flanigan et al., 1994). Catheter loss is rare with isolated erythema or serous drainage. Purulent drainage, should always be cultured. Positive cultures of normal appearing exit sites indicate the presence of colonization, not infection.

**Chronic Exit-Site Infection:** This may be the result of an untreated or inadequately treated acute infection. It may also be a sequela of a resolved acute infection which recurs after withdrawal of antibiotic therapy. Symptoms of chronic infection are similar to those of acute infections; however, exuberant granulation tissue is more common both externally and in the sinus. Granulation tissue at the external exit is sometimes covered by a large stubborn crust or scab. Pain, erythema, and swelling are frequently absent in chronic infection.

**An Equivocal Exit Site:** This is defined as purulent and/or bloody drainage only in the sinus that cannot be expressed outside, accompanied by regression of the epithelium and the occurrence of slightly exuberant granulation tissue in the sinus. Erythema may be present but with a diameter less than twice the width of the catheter. Pain, swelling, and external drainage are absent

(Twardowski and Prowant, 1996b). The equivocal infected exit site represents low grade infection. Although some equivocal exits improve spontaneously, most progress to overt infection if untreated.

**Tunnel Infection:** Tunnel infection is defined as erythema, edema, and/or tenderness over the subcutaneous pathway, and may be characterized by intermittent or chronic, purulent, bloody, or gooey drainage which discharges spontaneously or after pressure on the cuff. Tunnel infections are often occult (Plum et al., 1994) and can sometimes be detected by ultrasonography of the subcutaneous pathway (Plum et al., 1994; Holley et al., 1989). Most, but not all, tunnel infections occur in association with exit-site infections. Here the risk for subsequent peritonitis is increased.

**Traumatized Exit Site:** Traumatized exit-site appearances depend on the intensity of the trauma and the time interval until examination. Common features are pain, bleeding, scab, and deterioration of exit appearance.

**Pathogens:** Staph. aureus is responsible for the majority of exit-site and tunnel infections. Pseudo. aeruginosa is much less common, but like Staph. aureus, is difficult to eradicate and frequently leads to peritonitis if catheter removal is delayed. Staph. epidermidis is a relatively infrequent cause of tunnel infection in contrast to peritonitis. Other gram-positive organisms, other gram-negative bacilli, and, rarely, fungi account for the remaining infections.

Exit-Site Cultures: Within 2 — 4 weeks after catheter implantation, almost all exit sites are colonized by bacteria. Positive cultures from normal-appearing exit sites indicate colonization, not infection. Whenever possible, the cultures should be taken from the exudate (Twardowski and Prowant 1996a, 1996c). Cultures should only be taken from abnormal-looking exit sites.

**Treatment of Exit-Site and Tunnel Infections**

Exit-site, tunnel, and cuff infections require antibiotic therapy.

**Antibiotics:** Table 2 outlines the evaluation and treatment of exit-site and tunnel infections (Twardowski and Prowant, 1997; Keane et al., 1996). Antibiotic therapy should be started immediately for tunnel and exit-site infections, pending culture results.

| TABLE 2 | | | | |
|---|---|---|---|---|
| Exit-Site Treatment for Each Category of Exit-Site Appearance | | | | |
| | Equivocal infection | Acute infection | Chronic infection | Cuff infection |
| Evaluation | Culture and sensitivities on peri-exit smear<br><br>Gram Stain | Culture and sensitivities on exudate<br><br>Gram Stain | Culture nad sensitivities on exudate<br><br>Gram stain | Palpation of cuff and tunnel<br><br>Culture and sensitivities and Gram stain of |

|  |  |  |  | exudate (spontaneous or after pressure on cuff) Ultrasound and cuff/tunnel |
| --- | --- | --- | --- | --- |
| Initial therapy | Cauterize slightly exuberant granulation tissue. Topical mupirocin | Cauterize slightly exuberant and exuberant granulation tissue. First generation cephalosporin for gram-pos. organisms, quinolone for gram-neg. organisms, vancomycin for MRSA | Cauterize slightly exuberant nad exuberant granulation tissue. If initial therapy: first generation cephalosporin for gram-pos. organisums; quinolone for gram-neg. organisms; vancomycin for MRSA If previously treated: add synergistic drug or change antibiotic according to culture and sensitivities. | Cauterize slightly exuberant and exuberant granulation tissue. Initial antibiotic therapy based on Gram stain results |
| 48 Hours | Change to Neosporin or gentamycin ointment if gram-neg. organisms on culture. | Adjust therapy according to culture and sensitivities. | Adjust therapy according to culture and sensitivities. | Adjust antibiotic according to culture and sensitivities |
| Follow-up | If no improvement in 2 weeks, change to systemic antibiotic based on initial culture and sensitivities. Continue therapy 7 days past achieving a good appearance. Response to systemic antibiotic therapy is excellent with cure occurring in almost all instances. | Evaluate weekly; reculture if no improvement. Substitute another appropriate antibiotic or add a second, synergistic antibiotic. Use rifampicin as a second antibiotic for staphylococcal infections. Most acute infections respond favorable to therapy. Continue to treat for 7 days after achieving a good appearance. If accompanying | Evaluate every 2 weeks; reculture every 2 weeks if no improvement on appropriate therapy. If infection recurs repeatedly after achieving a good appearance: 1. Consider chronic antibiotic suppression, 2. if no improvement after a month of treatment, suspect cuff infection and treat as such. If accompanying peritonitis, remove catheter. | Reevaluate every 2 weeks, reculture monthly. If no remission: 1. consider cuff shaving 2. consider catheter replacement. If accompanying peritonitis, remove catheter. |

| | | peritonitis, consider catheter removal. | | |
|---|---|---|---|---|

**Gram-Positive Organisms:** The initial antibiotic chosen should cover, at a minimum, gram-positive organisms. Oral penicillinase-resistant penicillins, oral trimethoprim/sulfamethoxazole, or cephalexin are reasonable, convenient, and cost-effective options (Keane et al., 1996; Flanagan et al., 1994). Vancomycin should be avoided in view of the emergence of VRE (Golper and Trananæus, 1996). Once culture results are available, the antibiotic can be adjusted. In slowly-resolving, or particularly severe-appearing, Staph. aureus exit-site infections, rifampin 300 mg twice daily in adults (5 — 10 mg/kg twice daily in children) may be added.

**Gram-Negative Organisms:** Quinolones are generally used for Pseudo. aeruginosa catheter infections; ceftazidime may be added if necessary (Kazmi et al., 1992; Taber et al., 1991). Chelation interactions may occur between fluroquinolones and concomitantly administered multivalent cations. Calcium salts, oral iron supplements, zinc, sucralfate, magnesium/aluminium antacids, and milk may reduce ciprofloxacin absorption by 75% — 90%; staggering of administration is advised.

**Chronic Exit-Site Infections:** In chronic exit-site, infection a combination of synergistic antibiotics is preferred to a single agent to avoid emergence of resistant organisms, since the therapy is continued over a prolonged period. In chronic infection, the bacterial flora or the antibiotic sensitivity may change during the course of treatment. Therefore, an unresponsive exit site may have to be cultured repeatedly for timely diagnosis. The response to treatment is usually slow. The features of the chronic infection change very slowly to those of an equivocal exit and then eventually to those of a good exit site.

The antibiotic therapy and local care of the exit site are continued until the desired features of a good exit are achieved. In some cases, exit features change to equivocal and remain as such for a long time. In such cases the systemic antibiotic may be discontinued and replaced with a topical antibiotic. Some cases of chronic infection may require long-term (6 months to several years) suppressive doses of a systemic antibiotic. Typically, these cases show reinfection on discontinuing the systemic antibiotic; it is likely that such cases represent undiagnosed, low grade external infection.

**Length of Therapy:** Unfortunately, there are few data on the optimal choice and length of antibiotic therapy, route of administration (oral, intraperitoneal, intravenous). Data on usefulness of local therapy for exit-site and tunnel infections are limited. Therapy should be continued until the exit site appears completely normal. Prolonged antibiotics may be necessary. If 3 — 4 weeks of antibiotics fails to resolve the infection, the catheter should be replaced. Alternatively, deroofing of the tunnel or exteriorization of the cuff may be performed while maintaining antibiotic therapy.

**Cuff Shaving:** The superficial cuff can be completely removed (exteriorized and shaved) when antibiotics do not resolve an infection (Scalamogna et al., 1991; Abraham et al., 1988). The variety of described techniques includes debridement of the area of cellulitis and revision of the tunnel. Subsequent peritonitis with the same organism occurs in approximately half of the

patients who undergo cuff shaving for Staph. aureus and may result in the eventual removal of the catheter.

**Topical Treatment:** Topical treatment may be used as an adjunct to systemic antibiotics in the treatment of exit infections or as initial therapy for low grade infection (equivocally infected exit). Topical antibiotic therapy is not appropriate for acute and chronic exit infections.

> 1. Hypertonic saline (3% NaCl solution) dressings may be beneficial in otherwise refractory episodes (Strauss et al., 1993). Other topical treatments include application of soaks to the exit 2 — 4 times per day, as well as the application of dry heat (Prowant et al., 1993; Gokal et al., 1993; Strauss et al., 1993). Soaking solutions include 0.9% saline, sodium hypochlorite, dilute hydrogen peroxide, and povidone iodine (Prowant et al., 1993). There are no controlled studies assessing the effectiveness of these topical treatments. 2. Equivocally infected exit sites can be treated with either local or oral antibiotics. The topical antibiotics that have been successfully used include mupirocin, gentamicin, and neosporin. Cauterization of the slightly exuberant granulation tissue in the sinus may be necessary. Systemic antibiotics may be used in cases unresponsive to topical therapy (Twardowski and Prowant, 1997).

**Care of the Infected Exit Site:** Increasing the frequency of exit-site care to once daily or even twice daily is the most frequent recommendation for care of infected exits (Prowant et al., 1993). Changing the cleansing agent is also common. An infected exit usually has regression of the epithelium in the sinus with the remainder of the visible sinus covered with granulation tissue (Twardowski et al., 1996b). These characteristics are similar to the healing exit, so it is important that cytotoxic agents are not allowed to enter the sinus. Large, irritating crusts may develop around infected exits. As in routine care, crusts or scabs should never be forcibly removed but they can be gradually softened with hydrogen peroxide, saline, soap and water, poloxamer, or exit soaks. Sterile dressings should be used for infected exits to absorb drainage, to reduce exposure to micro-organisms, and to protect the exit from trauma.

**Catheter Replacement:** There are several indications for catheter replacement for exit-site and tunnel infections. Catheter removal is appropriate when the inner cuff of the catheter is infected because the risk of peritonitis is high (Plum et al., 1994). Inner-cuff infection may be associated with peritonitis in the absence of sinus or external-cuff infection. Other conditions include refractory or recurrent peritonitis with exit or tunnel infections or extensive cellulitis (with the same organism) unresponsive to antibiotics. Simultaneous replacement of the catheter in such cases is feasible (Schroeder et al., 1993; Swartz et al., 1991). When an exit-site, cuff, or tunnel infection is associated with peritonitis due to the same organism, catheter removal should be considered unless the organism is Staph. epidermidis (Gupta et al, 1996). Although antibiotics may lead to clearing of the effluent, the culture often remains positive and the peritonitis will recur unless the source (the catheter) is removed. The timing of catheter removal for refractory catheter infections is uncertain; prolonged antibiotic therapy may be prescribed, which may be of 6 — 8 weeks duration.

**Outcome:** The response to antibiotics is highly dependent on the organism. Approximately 50% of Staph. aureus and Pseudo. aeruginosa catheter infections in contrast to 90% of Staph. epidermidis infections (Scalmogna et al., 1991; Kazmi et al., 1992; Abraham et al., 1988) resolve with an initial course of 2 — 4 weeks of antibiotic therapy.

**RECOMMENDATIONS**

1. Antibiotic therapy is essential for established exit and tunnel infections. The recommendations are outlined in Table 2. 2. Duration of therapy is for a minimum of 2 weeks, at which stage the nonresponders need further evaluation and therapy. 3. Therapy with cuff shaving may be successful in difficult situations but long-term outlook for these catheters in not good. 4. Topical applications may cure equivocally infected exits; they are of no proven value in eradication of overt infections. 5. Catheter removal is essential in nonresponding tunnel infections, especially where there is associated peritonitis. 6. Increased frequency of exit-site care (1 — 2 times daily) is recommended when there is an exit or tunnel infection. Crusts should not be forcibly removed.

## PREVENTION OF CATHETER INFECTIONS

### Nasal Carriage

Staphylococcus aureus nasal carriage, defined by one positive culture from the nares, is a risk factor for Staph. aureus infection. There have been four protocols demonstrated to be effective in preventing Staph. aureus catheter infections. Treatment of Staph. aureus nasal carriage with intranasal mupirocin twice daily for 5 days is effective in lowering Staph. aureus catheter infections in nasal carriers (Mupirocin Study Group, 1996; Perez—Fontan et al., 1993). The therapy must be repeated either monthly or when the nose culture again becomes positive for Staph. aureus. The disadvantages of the intranasal approach are expense and the need for repeated nose cultures (if therapy is based on positive cultures only). Alternative approaches to decreasing Staph. aureus infections, which are not dependent on obtaining nose cultures, include cyclical rifampin, 600 mg per day for 5 days given every 12 weeks, or mupirocin to the exit site as part of routine daily care (Zimmerman et al, 1991; Bernardini et al., 1996). Prophylactic use of rifampin leads to significant side effects in 12% of patients, as well as rifampin resistance, obviating the use of this drug for therapy. Therefore, the use of rifampin for prophylaxis is not recommended. All approaches reduced Staph. aureus exit-site infections to one third of the previous rate.

### Trauma to Catheter Tract

Twardowski and Prowant (1996a) found that documented trauma preceded exit-site deterioration in all exit sites previously classified as perfect and in half of those previously classified as good. The proposed definition of trauma is anything that breaks the integrity of the skin at the exit site, or the epithelium or granulation tissue in the sinus. The definition also includes a pull on the catheter sufficient to disrupt tissue ingrowth at the cuff.

### RECOMMENDATIONS

1. Patients who are nasal carriers of Staph. aureus may receive prophylaxis; no one regimen of eradication is superior. As a maneuver to prevent exit-site infections, application of mupirocin to the exit site as part of the daily routine is advocated. 2. Trauma to the catheter tract should be avoided by proper immobilization and should be reported to the dialysis unit if it causes severe pain or bleeding, or if there is subsequent deterioration of the exit-site appearance with redness, exudate, persistent pain or tenderness.

## NONINFECTIOUS (MECHANICAL) CATHETER COMPLICATIONS

The most important noninfectious complications during PD are abdominal wall-related hernias, leakage of dialysis fluid, and in/outflow malfunction of the catheter.

**Incisional Hernia**

Before PD treatment is started, all significant abdominal wall-related hernias should be corrected. Otherwise, the hernia will become worse because of the increased pressure on the abdominal wall created by intraperitoneal dialysis fluid. The most frequently occurring hernias during PD are incisional, umbilical, and inguinal.

Incisional hernia through the catheter placement site, is more frequent if the implantation of the catheter is made through the midline, instead of a paramedial approach through the rectus muscle.

A significant hernia should primarily be repaired surgically; if not, the risk of enlargement of the hernia sac with inadequate drainage of the dialysis fluid from the abdominal cavity will significantly increase. After surgical repair, intermittent PD may be continued postoperatively using low volumes in a supine position. However, one should consider 3 — 4 weeks of HD after surgery in order to minimize the risk for recurrent or relapsing herniation.

**Leakage**

This complication is related to the catheter implantation technique, trauma, and/or patient-related anatomical abnormalities. It can occur early ( <30 days), or late ( >30 days), after implantation following the start of PD, and can have different clinical manifestations depending on whether the leak is external or subcutaneous.

Early Leakage ( <30 days): This is usually external, appearing as fluid through the wound or the exit site. When PD is commenced soon after catheter implantation, subcutaneous leakage may develop at the site of the incision and entry into the peritoneal cavity. The exact site of the leakage can be determined with computerized tomography after infusion of 2 L of dialysis fluid containing radio-contrast material (Twardowski et al., 1990). If the leakage is apparent at the exit site or through the wound, the risk of a tunnel infection and/or peritonitis is increased. Prophylactic antibiotic therapy needs to be considered.

Peritoneal dialysis should be interrupted when early subcutaneous leakage develops. It may seal off during a prolonged rest period. Genital swelling as part of a subcutaneous early leak through the intra-abdominal wall is often a sign of a large leakage and should, in most cases, result in an exploration of the incision site. The other cause of genital swelling is a patent processus vaginalis; computerized tomography will usually differentiate between the two.

**RECOMMENDATIONS**

1. A period off PD (1 — 2 weeks) should be instituted during which the patient, if needing dialysis, is maintained on hemodialysis. Limited, small-volume supine PD may suffice. 2. For a recurrent leak, surgical repair is essential and the site of the leak may be localized using computerized tomography.

Late Leakage ( >30 days): Late dialysis fluid leakage into the subcutaneous tissue is sometimes occult, difficult to diagnose, and may present as a diminished drainage, which might be mistaken for ultrafiltration failure. Computerized tomography of the abdomen, filled with PD fluid and added contrast media, or abdominal scintigraphy with technetium-99m (Kopecky et al., 1987; Twardowski et al., 1990) may identify the leak. Exploration of the area of the inner cuff only

rarely results in an identification of the leakage site. The management is essentially as above. If this is not effective the catheter must be removed.

## Outflow/Inflow Obstruction

Outflow and inflow obstruction are the most frequently observed early events within 2 weeks after catheter implantation, although these complications can be seen later during PD-related complications such as peritonitis. It is important to differentiate between the various causes:

1. Mechanical obstruction (tip migration, kink in external tubing, clamp); 2. Constipation; 3. Catheter blockage.

**Outflow Obstruction:** Outflow obstruction (one-way obstruction) is the most frequent problem characterized by poor flow and failure to drain the peritoneal cavity. The pathogenesis includes intraluminal catheter factors such as debris (blood clot or fibrin), or extraluminal factors that comprise the following:

1. Stool-filled bowel enwrapping the catheter (constipation); 2. Occlusion of the catheter holes from pressure exerted by adjacent organs; 3. Omental wrapping; 4. Catheter tip dislocation out of the true pelvis; 5. Tip entrapment in peritoneal pockets conditional on adhesions; 6. Incorrect catheter placement at implantation.

Although one-way obstruction is the most common form, two-way obstructions do exist. Also, a reversed one-way obstruction is known, wherein the fluid can be drained but the next infusion cannot be performed due to a clot within the catheter lumen (Twardowski and Pasley, 1994).

**Inflow Obstruction:** Inflow obstruction is related to either kinking of the catheter, often in the subcutaneous tunnel, or intraluminal debris.

## RECOMMENDATIONS

Before treating a catheter obstruction, the type of obstruction must be established, if necessary, by catheter fluoroscopy. The treatment includes:

1. Conservative or noninvasive approaches such as body position change, walk on staircases, laxatives, flushing with heparinized saline (""push-and-suck"" maneuver) should be undertaken. If these fail, then instillation of fibrinolytic agents (urokinase, streptokinase 10 000 U in 2 mL left in the catheter for 2 hours) may be tried. In the case of recurrent fibrin clots, heparin in doses of 500 — 2000 U/L dialysis fluid may prevent obstruction. 2. Aggressive therapies include (a) blind techniques using fluoroscopically-guided stiff wires or stylet manipulation (rotating maneuver) (Stegmayr et al., 1993) combined with the whiplash technique (Honkanen et al., 1990), cleaning out with a Fogarty catheter, or use of an intraluminal brush; (b) direct or visualized techniques of peritoneoscopy, open surgical catheter revision, or catheter replacement.

The rate of success of the different treatment procedures has not been evaluated in randomized trials. However, it is reasonable to begin with the noninvasive procedures before more drastic steps are employed. The sequence of steps is as follows:

1. Examination and evaluation, 2. Laxatives,3. Urokinase, 4. Fluoroscopy and manipulation, 5. Revision, 6. Replacement.


## POSTTRANSPLANT CARE OF THE CATHETER

For transplant patients who have a peritoneal catheter in situ, dressing changes should be performed weekly until the catheter is removed (commonly 4 — 12 weeks posttransplant). There is no need to obtain peritoneal cultures routinely; cultures should only be obtained when clinically indicated by infusing saline solution and culturing the effluent; in this setting cell counts may not be meaningful. At the time of transplantation, any infected catheters should be removed with appropriate antibiotic cover.

## RECOMMENDATION FOR CATHETER OUTCOME EVALUATION

All centers should maintain data that, on subsequent analysis, would provide information on catheter survival, exit infection, and peritonitis. Outcome data are important and should denote whether a catheter is still functioning when removed and the reasons for removal.

## SUMMARY

The peritoneal catheter is the PD patient''s lifeline. Advances in catheter knowledge have made it possible to obtain access to the peritoneal cavity safely and to maintain access over an extended period of time. Catheter-related infections remain a major problem, solutions for which are being actively researched. Nevertheless, the successful outcome of a catheter is very much dependent on meticulous care and attention to detail. Adherence to the principles of catheter insertion and subsequent management and care remain the cornerstone of successful PD access. The guidelines provided in this publication represent a consensus view based on studies from the literature and opinions of experts in this field; it is hoped that implementation of these guidelines will improve catheter-related outcomes and, therefore, enhance patient care.

### Acknowledgment

## APPENDIX: GUIDELINES FOR PERITONEAL DIALYSIS CATHETERS FOR PEDIATRIC PATIENTS

Continuous ambulatory peritoneal dialysis has been the most frequently prescribed dialysis modality for pediatric patients under 15 years of age living in North America and in many European countries (Alexander and Honda, 1993; US Renal Data System 1996; Warady et al., 1997). For children, as for adults, a reliable peritoneal catheter is the cornerstone of successful peritoneal dialysis (PD). Unfortunately, there have been no controlled comparative studies of chronic peritoneal catheters in pediatric patients. Available information is entirely descriptive, although several large, multicenter, collaborative pediatric studies have made important observations on the relative merits of various catheter designs. The following recommendations rely heavily on those observational studies and should not be construed as truly ""evidence-based"" treatment guidelines. With the maturation of continuous PD as the primary maintenance dialysis therapy for children awaiting renal transplantation, controlled studies comparing available catheter configurations in pediatric patients should become a priority.

### Peritoneal Catheters

As with catheters designed for adult patients, the ideal pediatric catheter provides rapid dialysate inflow and outflow rates without leaks or infections. There is minimal catheter movement at the skin exit site, and the catheter is placed at a location that is both reachable and visible to the

patient and/or caregivers. In addition, painful dialysate flow, in or out, is never acceptable when the patient is a child.

For most of the available adult catheters, there are comparable pediatric models that are generally shorter and smaller in internal and external diameters than their adult catheter counterparts. Pediatric and adult patients differ with respect to body size, underlying renal diseases, their associated anatomical and surgical features, and the routine performance of the dialysis procedures by alternate caregivers. However, no clearly superior pediatric catheter design has emerged, and the use of ""adult""-sized and configured peritoneal catheters is commonly seen in all but the smallest pediatric patients (Alexander et al., 1985; Hymes et al., 1986; Watson et al., 1985).

Types of Catheters: Currently, most pediatric patients are treated with surgically placed, standard Tenckhoff catheters. For example, the most recent data available from the Dialysis Arm of the North American Pediatric Renal Transplant Cooperative Study (NAPRTCS) identify catheter types used in 1126 independent courses of PD treatment in children reported from 65 pediatric dialysis centers in the United States, Canada, Mexico, and Costa Rica between 1992 and 1996 (Lerner et al., 1997). Tenckhoff catheters were used in 1078 (96%) courses of treatment, Toronto—Western Hospital catheters in only 8 (0.7%) courses, and a variety of other catheter types in 70 (6%) courses of PD treatment. The pediatric experience in Japan showed that 100% of 345 children followed for 10 years or longer were treated with a Tenckhoff catheter (Honda, 1997). An early report from the Italian Registry of Pediatric Chronic Peritoneal Dialysis noted the use of the Valli catheter in 27 of 188 (14%) courses of PD treatment performed between 1986 and 1991 (Verrina et al., 1993). A subsequent report from the Italian registry suggests that, as in North America and Japan, standard Tenckhoff catheters are now used in more than 95% of pediatric patients in Italy (Verrina et al., 1995).

Despite this apparent worldwide consensus favoring Tenckhoff catheters for pediatric patients, controversy exists over the optimum configuration of the intraperitoneal segment (straight or coiled), shape of subcutaneous tunnel (straight or permanent bend), and the orientation of the catheter skin exit site (up, down, or lateral).

**Coiled or Straight Tenckhoff Catheters:** Early in the development of continuous PD for children, the use of Tenckhoff catheters with straight intraperitoneal segments was routinely reported. Concerns about dialysate inflow pain and other mechanical catheter problems, such as complete or partial obstruction, may have subsequently led pediatric centers to favor Tenckhoff catheters with curled intraperitoneal segments. In a recent report from 18 pediatric PD treatment centers in the United States and Canada, the curled Tenckhoff design was noted to be the first choice of 88% of the centers reporting (Neu et al., 1995). NAPRTCS data on over 1000 courses of PD treatment in children confirm the use of coiled Tenckhoff catheters in the majority of pediatric patients (59%), nearly twice as many as used straight Tenckhoff catheters (34%) (Lerner et al., 1997).

Available data do not establish the superiority of the coiled over the straight Tenckhoff design in children, although mechanical failures may be seen less frequently with coiled catheters. In a review of 1383 courses of PD treatment in pediatric patients, peritonitis rates were found to be identical to straight and coiled Tenckhoff catheters (one episode per 13.4 months) (Warady et al., 1996). In a subsequent report, catheter revision rates for all reasons were also very similar between the two catheter types. Revision rates were reported as the ""access revision ratio"" (number of revisions/number of catheters at risk). Straight Tenckhoff catheters had a revision

ratio of 0.26 (108 revisions/415 catheters at risk), compared to 0.19 (138/741) for coiled Tenckhoff catheters (Lerner et al., 1997). However, mechanical malfunction as a cause for catheter revision was more frequently seen among straight catheters. Forty-nine of 415 straight catheters (12%) failed due to mechanical malfunction (primarily obstruction) compared to 45 or 741 (6%) coiled catheters (Lerner et al., 1997).

The incidence of inflow pain has never been studied systematically in children.

**One or Two Subcutaneous Cuffs:** Early pediatric experience with double-cuff Tenckhoff catheters was unsatisfactory (Alexander and Tank, 1982; Watson et al., 1985). The superficial cuff was large and tended to migrate to the skin exit site, leading to skin erosion and eventual exit-site/tunnel infection. Superficial cuff erosion seemed to occur frequently in children, perhaps because most pediatric patients have less abdominal wall adipose and muscle tissue than adults. The adoption of single-cuff Tenckhoff catheters resulted in avoidance of superficial cuff erosion, but subsequent observations have suggested that the use of a single cuff is associated with higher peritonitis rates in children. NAPRTCS found a significantly higher peritonitis rate of one episode per 12.6 months in children with single-cuff catheters, compared to a rate of one episode per 15.1 months when two cuffs were present (p = 0.01) (Warady et al., 1996). In addition, the time to the first episode of peritonitis was significantly delayed when two cuffs were used (p = 0.02).

**Straight or Permanent Bend Tunnel Configuration:** The use of the permanent bend (Swan neck) tunnel configuration in pediatric patients has increased from 16% reported by the NAPRTCS in 1994 (Kohaut and Tejani, 1996) to 21% in the most recent data (Lerner et al., 1997). At first, some pediatric catheter surgeons may have been reluctant to create the large subcutaneous Swan neck tunnel track, with its attendant local tissue trauma; now there are smaller versions of the Swan neck catheter available for children. For the smallest patients, the Swan neck tunnel can be placed in the center of the abdomen curving over the umbilicus like an inverted horseshoe.

Recent observations have shown no significant differences in overall outcomes between catheters with Swan neck and straight tunnel configurations. In one study, peritonitis rates were lower with Swan neck catheters although this difference was not significant (Warady et al., 1996). Subsequent analysis showed that more Swan neck catheters required revision due to exit-site/tunnel infections (5% compared to 1% of straight catheters) (Lerner et al., 1997).

**Exit-Site Orientation:** The clear superiority of a downward (caudad) pointing exit site has been demonstrated in a large cohort of pediatric patients. Peritonitis rates were one episode per 18.8 months when the exit site pointed down, compared to one episode per 10.6 months when the exit site pointed upward (p = 0.010) (Warady et al., 1996).


**Actuarial Catheter Survival Rates**

Limited information is available on actuarial catheter survival rates in pediatric patients. A large Italian study reported 79.7% catheter survival at 1 year, 66.6% at 2 years, 42.8% at 3 years, and 39.8% at 4 years (Verrina et al., 1993). Recent data from Japan show overall actuarial catheter survival rates to be similar to those reported from Italy but to be different according to patient age group and whether one or two cuffs were used. Actuarial catheter survival was 72.2% versus 81.0% at 1 year, and 45.9% versus 52.6% at 3 years, for children <6 years of age versus older

children. Single-cuff catheter survival rates were 69% and 43.2% at 1 and 3 years, respectively, compared to 82.2% and 54.2% for double-cuff catheters (Honda, 1997).

**The Infant and Small Child**

Peritonitis rates and catheter revision rates were reported to be higher in younger children treated in North America (Warady et al., 1996) and Japan (Honda, 1997). Recent reports have called attention to the more frequent use of single-cuff catheters and upward-pointing exit sites in younger compared to older children (Warady et al., 1996; Honda, 1997; Lerner et al., 1997). The effects of the number of catheter cuffs and the catheter exit-site orientation on catheter survival and peritonitis rates have been shown to be independent of age group effects (Honda, 1997). It has been suggested that the use of double-cuff catheters and downward-pointing exit sites in younger patients could improve outcomes in this high-risk patient group (Warady et al., 1996).

Placement of the catheter exit site in a presternal location with a Swan neck tunnel configuration has been reported to reduce the number of catheter-related infections in the small number of children in whom this novel approach has been attempted (Sieniawska et al., 1993). The utility of the presternal configuration may be limited in children by the need to periodically lengthen the subcutaneous portion of the catheter as the child grows.

**Catheter Insertion**

A survey of pediatric centers participating in the Paediatric Peritoneal Dialysis Study Consortium (PPDSC) revealed that placement of the catheter by a surgeon in the operating room was the preferred method in all but a single center (Neu et al., 1995). In general, it was felt that infants and young children with vesicostomies, ureterostomies, or colostomies required location of the skin exit site as far from the stoma as possible to reduce the risk of contamination and infection. Location of the exit site on the side of the abdomen away from a gastrostomy exit site was also recommended. Prophylactic perioperative antibiotics were routinely used in a majority of the PPDSC centers surveyed (Neu et al., 1995).

Hernias are common in young children receiving chronic PD (Verrina et al., 1992) due in part to the thin abdominal wall and persistent patent processus vaginalis present in younger children. At the time of surgical catheter placement, an effort should be made to identify and repair any abdominal wall or inguinal hernias and to close a patent processus vaginalis (Clark et al., 1992; Conlin and Tank, 1995).

The role of routine omentectomy in children remains controversial. At least partial removal of omental tissue during initial surgical catheter placement is advocated by some (Alexander and Tank, 1982; Fonkalsrud, 1990; Clark et al., 1992; Conlin and Tank, 1995), but not by others (Lewis et al., 1995). Routine omentectomy was performed in just over half of the centers responding to the PPDSC survey (Neu et al., 1995).

**Exit-Site Skin Care**

Exit-site infections are reported in up to 60% of pediatric patients (Levy et al., 1990). The use of chlorhexidine during cleansing was found to be associated with a significant decrease in the frequency of exit-site infections when compared to the use of povidone iodine. A large international survey of chronic exit-site care practices in adult and pediatric centers documented the wide variety of protocols in use, but shed no light on the relative effectiveness of the different approaches to exit-site management in children and adults (Prowant et al., 1993).

**RECOMMENDATIONS**

1. An actuarial catheter survival rate approaching 80% at 1 year is a reasonable goal for pediatric patients. However, lower catheter survival rates can be expected in younger children. 2. Reported experience in pediatric patients is generally limited to various configurations of the Tenckhoff catheter. Recommendations regarding catheter types other than the Tenckhoff cannot be made with the available data. 3. Coiled and straight Tenckhoff catheters perform well in pediatric patients. The former may be associated with fewer obstructive events and less inflow pain, but definitive data are lacking. 4. ""Pediatric""-sized catheters are available in most configurations. It is not clear that such catheters are necessary in any but the smallest pediatric patients. 5. The use of a catheter with two subcutaneous cuffs is recommended at all ages. 6. The use of a tunnel with a downward-pointing skin exit site is recommended at all ages. 7. Recommendations for perioperative catheter planning and care in children are not different from adult patient recommendations. 8. Recommendations for the prevention, diagnosis, and management of skin exit-site and tunnel infections in pediatric patients are not different from adult patient recommendations.

## SELECTED READINGS

Abraham G, Savin E, Ayiomamitis A, Izzatt S, Vas SI, Mathews RB, et al. Natural history of exit-site infections in patients on CAPD. Perit Dial Int 1988; 8:211—16.

Akyol AM, Porteous C, Brown MW. A comparison of two types of catheters of CAPD. Perit Dial Int 1990; 10:63—6.

Alexander SR, Tank ES. Surgical aspects of continuous ambulatory peritoneal dialysis in infants, children and adolescents. J Urol 1982; 127:501—4.

Alexander SR, Tank ES, Corneil AT. Five years'' experience with CAPD/CCPD catheters in infants and children. In: Fine RN, Scharer K, Mehls O, eds. CAPD in children. New York: Springer—Verlag, 1985:174—89.

Alexander SR, Honda M. Continuous peritoneal dialysis for children: A decade of world wide growth and development. Kidney Int 1993; 44(Suppl 43): S104—9.

Ash SR. Chronic peritoneal dialysis catheters: Effects of catheter design, materials and location. Semin Dial 1990; 3:39—46.

Ash SR, Janle EM. T-Fluted peritoneal dialysis catheter. In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1993; 9:223—6.

Ash SR, Daugirdas JT. Peritoneal access devices. In: Daugirdas JJ, Ing TS, eds. Handbook of dialysis. Boston: Little, Brown and Co, 1994:275—300.

Ash SR, Nichols WK. Placement, repair, and removal of chronic peritoneal catheters. In: Gokal R, Nolph KD, eds. Textbook of peritoneal dialysis. Dordrecht: Kluwer Academic, 1994:315—33.

Bernardini J, Piraino B, Holley JL, Johnstone JR, Lukes R. Randomized trial of Staph. aureus prophylaxis in PD patients: mupirocin calcium ointment 2% applied to the exit site versus oral rifampin. Am J Kidney Dis 1996; 26:695—700.

Bonzel KF, Lettgen B, Bald M, Kleine L, Erhard J. Bent subcutaneous catheter shape for regular dialysis treatment in children. Perit Dial Int 1993; 13(Suppl 2): S263—6.

Clark KR, Forsythe JL, Rigg KM, Sharp J, Rangecrofit L, Wagget J, et al. Surgical aspects of chronic peritoneal dialysis in the neonate and infant under one year of age. J Pediatr Surg 1992; 27: 780—3. Conlin MJ, Tank ES. Minimising surgical problems of peritoneal dialysis for children. J Urol 1995; 154:917—19.

Cruz C. Clinical experience with a new peritoneal access device (the Cruz catheter). In: Ota K, Maher J, Winchester J, Herszel P, eds. Current concepts in peritoneal dialysis. Tokyo: Excerpta Medica, 1992:164—9.

Dryden MS, Ludlam HA, Wing AT, Phillips I. Active intervention dramatically reduces CAPD-associated infections. In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Bulletin, 1991; 7:125—8.

Eklund BH, Honkanen EO, Kalan AR, Kyllonen LE. Catheter configuration and outcome in CAPD: a prospective comparison of two catheters. Perit Dial Int 1994; 14:70—4.

Eklund BH. Surgical implantation of CAPD catheters: Presentation of midline incision-lateral placement method and a review of 110 procedures. Nephrol Dial Transplant 1995; 10:386—90.

Eklund BH, Honkanen EO, Kalan AR, Kyllonen LE. Peritoneal dialysis access: Prospective randomized comparison of the Swan neck and Tenckhoff catheters. Perit Dial Int 1995; 15:353—6.

Favazza A, Petri R, Montanaro D, Boscutti G, Bresakola F, Mioni G. Insertion of a straight peritoneal catheter in an arcuate subcutaneous tunnel by a tunneler: long-term experience. Perit Dial Int 1995; 15:357—62.

Flanagan MJ, Hochstetter LA, Langholdt D, Lim VS. CAPD catheter infections: diagnosis and management. Perit Dial Int 1994; 14:248—54.

Fonkalsrud EW. Ask the expert: Advice concerning the need for omentectomy in babies and children receiving chronic ambulatory peritoneal dialysis. Paediatr Neph 1990; 4:574.

Gokal R, Ash SR, Helfrich BG, Holmes CJ, Joffe P, Nichols W, et al. Peritoneal catheters and exit-site practices: Toward optimum peritoneal access. Perit Dial Int 1993; 13:29—39.

Golper TA, Brier ME, Bunke M. Risk factors for peritonitis in long-term peritoneal dialysis: The Network 9 Peritonitis and Catheter Survival Studies. Am J Kidney Dis 1996; 38:428—36.

Golper TA, Tranææus A. Vancomycin revisited. Perit Dial Int 1996; 16:116—17.

Gupta B, Bernardini J, Piraino B. Peritonitis associated with exit-site and tunnel infections. Am J Kidney Dis 1996; 28:415—19.

Hasbargen BJ, Rodgers DJ, Harbargan JA, Quinn MJ, James MK. Exit-site care —— is it time for a change? Perit Dial Int 1993; 13(Suppl 2):S313—15.

Holley JG, Foulkes CJ, Mers AH, Willard D. Ultrasound as a tool in the diagnosis and management of exit-site infections in patients undergoing CAPD. Am J Kidney Dis 1989; 14:211—16.

Honkanen E, Eklund B, Laasonen L, Ylinew K, Gronhagen—Riska C. Re-position of a displaced peritoneal catheter: the Helsinki whiplash method. In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Bulletin, 1990; 6:159—64.

Honda M. The Japanese experience with CAPD/CCPD in children. In: Fine RN, Warady BA, Alexander ST, eds. CAPD/CCPD in children. 2nd ed. Dordrecht: Kluwer Academic, 1997 (in press).

Honda M, Litaka K, Kawaguchi H, Hoshi S, Akashi S, Kohsaa T, et al. The Japanese National Registry Data in Pediatric CAPD Patients: A report of the study group of pediatric conference. Perit Dial Int 1996; 16:269—75.

Hwang TL, Huang CC. Comparison of Swan neck catheter with Tenckhoff catheter for CAPD. In: Khanna R, ed. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1994; 10:203—5.

Hymes LC, Clowers B, Mitchell C, Warshaw BL. Peritoneal catheter survival in children. Perit Dial Bull 1986; 6:185—7.

Kazmi HR, Raffone FD, Kliger AS, Fenkelstein FO. Pseudomomas exit-site infections in CAPD patients. J Am Soc Nephol 1992; 2:1498—501.

Keane WF, Alexander SR, Bailie GR, Boeschoten E, Gokal R, Golper TA, et al. Peritoneal dialysis-related peritonitis treatment recommendations: 1996 update. Perit Dial Int 1996; 16:557—73.

Khanna R, Oreopoulos DG. Clinical management of patients on CAPD. Perit Dial Bull 1983; 3:54—7.

Khanna R, Twardowski ZJ. Recommendations for treatment of exit-site pathology. Perit Dial Int 1996; 16(Suppl 3):S100—4.

Kohaut EC, Tejani A. The 1994 annual report of the North American Pediatric Renal Transplant Cooperative Study. Pediatr Nephrol 1996; 10: 422—34.

Kopecky RT, Frymoyer PA, Witanowska LA, Thomas FD. Complications of CAPD: diagnostic value of peritoneal scintigraphy. Am J Kidney Dis 1987; 10:123—32.

Lee HB, Churg SH, Park MS. Effect of prolonged subcutaneous implantation of peritoneal catheters on peritonitis rates during CAPD. Blood Purif 1994; 12:186—7.

Lee HB, Park MS, Cha MK, Kim JH, Song K, Moon C. The peritoneal access. Perit Dial Int 1996; 16(Suppl 1):S322—6.

Lerner GR, Warady BA, Sullivan EK, Alexander SR. Chronic peritoneal dialysis and hemodialysis in children: The 1996 annual report of the dialysis arm of the North American Pediatric Renal Transplant Cooperative Study. Pediatr Nephrol 1997 (in press).

Levy M, Balfe JW, Geary D, Fryer—Keene S, Bannatyne R. Exit-site infection during continuous and cycling peritoneal dialysis in children. Perit Dial Int 1990; 10:31—5.

Lewis M, Webb N, Smith T, Roberts D. Routine omentectomy is not required in children undergoing chronic peritoneal dialysis. In: Khanna R, ed. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1995; 11:293—5.

Lewis SL, Prowant BF, Douglas C, et al. Nursing practice related to peritoneal catheter exit-site care and infections. ANNA J 1997 (in press).

Linblad AS, Hamilton RW, Nolph KD, Novak JW. A retrospective analysis of catheter configuration and cuff type: A National CAPD Registry report. Perit Dial Int 1988; 8:129—33.

Lineaweaver W, Howard R, Soney D. Topical antimicrobial toxicity. Arch Surg 1985; 120: 267—70.

Lupo A, Tarchini R, Cancarini G, Catizone L, Cocchi R, De Vecchi A, et al. Long-term outcome in CAPD: A 10 year survey by the Italian Cooperative Peritoneal Dialysis Study Group. Am J Kidney Dis 1994; 24:826—37.

Luzar MA, Brown C, Balf D, Hill L, Issad B, Monnier B, et al. Exit-site care and exit-site infections in continuous ambulatory peritoneal dialysis (CAPD): results of a randomized multicenter study. Perit Dial Int 1990; 10:25—9.

Lye WC, Lee EJ, Tan CC. Prophylactic antibiotics in the insertion of Tenckhoff catheters. Scand J Urol Nephrol 1992; 26:177—80.

Lye WC, Kour N—W, van der Straaten J, et al. A prospective randomized comparison of the Swan neck, coiled and straight Tenckhoff catheters in patients on CAPD. Perit Dial Int 1996; 16(Suppl 1):S333—5.

Mellotte GJ, Ho CA, Morgan SH, Bending MR, Eisinger AJ. Peritoneal dialysis catheters: A comparison between percutaneous and conventional surgical placement techniques. Nephrol Dial Transplant 1993; 8:626—30.

Moncrief JW, Popovich RP, Seare W, Sorrels AJ, Moncrief DB, Settle SM, et al. Peritoneal dialysis access technology: the Austin Diagnostic Clinic experience. Perit Dial Int 1996; 16(Suppl 1): S327—9.

Mupirocin Study Group. Nasal mupirocin prevents Staph. aureus exit-site infection during peritoneal dialysis. J Am Soc Nephrol 1996; 7:2403—8.

Nebel M, Marczewski K, Finke K. Three years'' experience with the Swan neck Tenckhoff catheter. In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Bulletin, 1991; 7:208—13.

Neu AM, Kohaut EC, Warady BA. Current approach to peritoneal access in North American children: a report of the Pediatric Peritoneal Dialysis Study Consortium. In: Khanna R, ed. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1995; 11:289—92.

Nielson PK, Hemmingsen C, Friis SU, Ladefoged J, Olgaard K. Comparison of straight and curled Tenckhoff peritoneal dialysis catheters implanted by the subcutaneous technique: a prospective randomized study. Perit Dial Int 1995; 15:18—21.

Oreopoulos DG, Baird—Helfrich G, Khanna R, Lum GM, Matthews R, Paulsen K, et al. Peritoneal catheters and exit-site practices: current recommendations. Perit Dial Bull 1987; 7:130—8.

Perez—Fontan M, Garcia—Falcon T, Rosales M, Rodrigues—Carmona A, Adeva M, Rodrigues—Lozana I, et al. Treatment of Staph. aureus nasal carriages in CAPD with mupirocin: long term results. Am J Kidney Dis 1993; 22:708—12.

Perit Dial Int 1996; 16(Suppl 3):S4—117.

Piraino B. Which catheter is the best buy? Perit Dial Int 1995; 15:303—4.

Plum J, Sudkamp S, Grabensee B. Results of ultrasound-assisted diagnosis of tunnel infections in CAPD. Am J Kidney Dis 1994; 23:99—104.

Prowant BF, Schmidt LM, Twardowski ZJ, et al. Peritoneal dialysis catheter exit-site care. ANNA J 1988; 15:219—23.

Prowant BF, Warady BA, Nolph KD. Peritoneal dialysis catheter exit-site care: results of an international study. Perit Dial Int 1993; 13:149—54.

Prowant BF, Twardowski ZJ. Recommendations for exit care. Perit Dial Int 1996; 16(Suppl 3):S94—9.

Scalmogna A, Castelnovo C, De Vecchi A, Ponticelli C. Exit-site and tunnel infection in CAPD patients. Am J Kidney Dis 1991; 18:674—77.

Schroeder CH, Severynen R, de Jong M, Monnem L. Chronic tunnel infection in children: Removal and replacement of CAPD catheter in a single operation. Perit Dial Int 1993; 13:198—200.

Scott PD, Bakran A, Pearson R, Riad H, Parrott N, Johnson R, et al. Peritoneal dialysis access. Prospective randomized trial of three different peritoneal catheters. Preliminary report. Perit Dial Int 1994; 14:289—90.

Sieniawska M, Roszkowska—Blaim M, Warchol S. Preliminary results with the Swan neck presternal catheter for CAPD in children. In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1993; 9:321—4.

Starzomski RC. Three techniques for peritoneal catheters exit site dressings. ANNA J 1984; 11:9—16.

Stegmayr BG, Hedberg B, Norrgard O. Stylet with a curved tip to facilitate introduction of new Tenckhoff catheters and reposition of replaced ones. Eur J Surg 1993; 159:495—7.

Strauss FG, Holmes D, Nortman DF, Friedman F. Hypertonic saline compresses: therapy for complicated exit site infections. In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1993; 9:248—50.

Swartz R, Messana J, Reynolds J, Ranjit U. Simultaneous catheter replacement and removal in refractory peritoneal dialysis infections. Kidney Int 1991; 40:1160—5.

Taber TE, Hegeman TF, York SM, Kinney RA, Webb DH. Treatment of pseudomonas infections in peritoneal dialysis patients. Perit Dial Int 1991; 11:213—16.

Tielens E, Nube MJ, de Wet JA, Limback J, Hofman X, Stettens A, et al. Major reduction of CAPD peritonitis after the introduction of the twin-bag system. Nephrol Dial Transplant 1993; 8:1237—43.

Turner K, Edgar D, Hair M, Uttley L, Sternland R, Hunt L, et al. Does catheter immobilization reduce exit-site infection in CAPD? In: Khanna R, Nolph KD, Prowant BF, Twardowski ZJ, Oreopoulos DG, eds. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Bulletin, 1992; 8:265—8.

Twardowski ZJ, Tully RJ, Ersoy FF, Dedhia NM. Computerized tomography with and without intraperitoneal contrast for determination of intra-abdominal fluid distribution and diagnosis of complications in peritoneal dialysis patients. ASAIO Trans 1990; 36:95—103.

Twardowski ZJ, Dobbie JW, Moore J, Nichols K, DeSpain JD, Anderson PC, et al. Morphology of peritoneal dialysis catheter tunnels. Macroscopy and light microscopy. Perit Dial Int 1991; 11:237—51.

Twardowski Z, Prowant B, Nichols K, Nolph KD, Khanna R. Six-years'' experience with Swan neck catheters. Perit Dial Int 1992; 12:384—9.

Twardowski Z, Khanna R. Peritoneal dialysis access and exit-site care. In: Gokal R, Nolph KD, eds. The textbook of peritoneal dialysis. Dordrecht: Kluwer Academic, 1994:271—314.

Twardowski ZJ, Pasley K. Reversed one-way obstruction of the peritoneal catheter (the accordian clot). Perit Dial Int 1994; 14:296—7.

Twardowski ZJ, Prowant BF, Pickett B, Nichols WF, Nolph KD, Khanna R. Four-year experience with Swan neck presternal peritoneal dialysis catheter. Am J Kidney Dis 1996; 27:99—105.

Twardowski ZJ, Prowant BF. Exit-site study methods and results. Perit Dial Int 1996a; 16(Suppl 3):S6—31.

Twardowski ZJ, Prowant BF. Classification of normal and diseased exit sites. Perit Dial Int 1996b; 16(Suppl 3):S32—50.

Twardowski ZJ, Prowant BF. Exit-site healing post catheter implantation. Perit Dial Int 1996c; 16(Suppl 3):S51—70.

Twardowski ZJ, Prowant BF. Current approaches to exit-site infections in patients on peritoneal dialysis. Nephrol Dial Transplant 1997; 12: 1284—95.

US Renal Data System 1992. Annual data report VI. Catheter related factors and peritonitis risk in CAPD patients. Am J Kidney Dis 1992; 20(Suppl 2):48—54.

US Renal Data System. USRDS 1996 annual data report. Bethesda, MD: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Disease, April, 1996:C5.

Verrina E, Andreetta B, Bassi S, Bonaudo R, Carringella, Castellani A, et al. Chonic peritoneal dialysis in pediatrics: experience of a national registry. Pediatr Nephrol 1992; 6:78—81.

Verrina E, Perfumo F, Zachello G, Edfonti A, Bassi S, Capasso G, et al. Chronic peritoneal dialysis catheters in pediatric patients: experience of the Italian Registry of Pediatric Chronic Peritoneal Dialysis. Perit Dial Int 1993; 13(Suppl 2):S254—6.

Verrina E, Zachello G, Perfumo F, Edfonti A, Sorino P, Bassi S, et al. Clinical experience in the treatment of infants with chronic peritoneal dialysis. In: Khanna R, ed. Advances in peritoneal dialysis. Toronto: Peritoneal Dialysis Publications, 1995; 11:281—4.

Warady BA, Jackson MA, Millspaugh J, Miller RM, Ford DM, Hellerstein M, et al. Prevention and treatment of catheter related infections in children. Perit Dial Bull 1987; 7:34—6.

Warady BA, Sullivan EK, Alexander SR. Lessons from the peritoneal dialysis patient database: a report of the North American Pediatric Renal Transplant Cooperative Study. Kidney Int 1996; 49(Suppl 53):S68—71.

Warady BA, Hebert D, Sullivan EK, Alexander SR, Tejani A. Renal transplantation, chronic dialysis and chronic renal insufficiency in children and adolescents: the 1995 annual report of the North American Pediatric Renal Transplant Cooperative Study. Pediatr Nephrol 1997; 11:49—64.

Watson AR, Vigneaux A, Hardy BE, Balfe JW. Six year experience with CAPD catheters in children. Perit Dial Bull 1985; 5:119—22.

Weber J, Mettang T, Hubel E, Kiefer T, Kuhlmann U. Survival of 138 surgically placed straight double cuff Tenckhoff catheters in patients on CAPD. Perit Dial Int 1993; 13:234—7.

Wikdahl AM, Engman U, Stegmayr B, Sorenson JG. One-dose cefuroxime i.v. and i.p. reduces microbial growth in PD patients after catheter insertion. Nephrol Dial Transplant 1997; 12:157—60.

Zimmerman SW, Ahrens E, Johnson CA, Craig W, Leggett J, O''Brien M, et al. Randomized controlled trial of prophylactic rifampin for PD related infections. Am J Kidney Dis 1991; 18:225—31.