

Access for Peritoneal Dialysis

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II.3

Introduction

The peritoneal dialysis (PD) catheter is as important to the establishment and maintenance of PD as the vascular access is for hemodialysis. Thus one of the primary objectives of a PD program should be the organization of a peritoneal access service geared to the implantation and maintenance of adequately functioning catheters in order to optimize the therapy and prolong this dialysis technique survival. Table 1 lists the characteristics of the ideal peritoneal access.

Historical Perspective

Clinical research in PD led to experimentation with PD catheters as early as 1923 [1]

Table 1. Characteristics of Ideal Peritoneal Access.

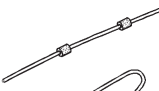
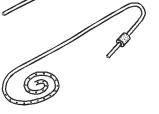
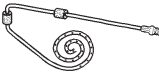
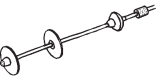
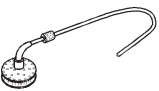
- Biocompatibility
- Resistance to bacteria
- Allows the abdominal wall to function normally
- Easily implantable/removable
- Will not migrate
- Allows for adequate flow without discomfort
- Requires minimal or no maintenance
- Has an integral adapter
- Can adept to any system/cycler used
- Is cosmetically acceptable to patients

with at that time seemingly ingenious means to instill and drain the dialysis solution from the abdomen [2 – 5]. Yet for many years PD access devices were plagued by 2 main problems which prevented the utilization of PD on a wider scale: obstruction caused by debris, fibrin or the apposition of intra-abdominal structures to the catheter orifice; and infection resulting from bacteria entering the peritoneal space not only via the catheter lumen but also along the catheter tract or the resulting cutaneo-peritoneal fistula.

These problems continued unsolved until the 1960's when Palmer and Quinton created the first modern PD catheter [6]. This consisted of a tubular structure of silicone rubber with multiple perforations in the distal segment which demonstrated better hydraulic function than previously used devices and with a low incidence of obstruction.

Tenckhoff and Schechter [7], who in 1968 published excellent long-term results on patients treated with PD with a remarkably low incidence of infectious complications improved upon this catheter. Their methods included, in addition to closed systems and meticulous handling of the connections and disconnections (2 fundamental elements in techniques used now) the use of Quinton and Palmer's catheter with 2 important refinements: the distal segment was elongated and coiled to further improve its hydraulic function and Dacron velour cuffs were placed in its midsection separated by 10 cm. The Dacron velour cuffs lead a dual function: they provide structural support by the abdominal

Table 2. Specifications, Materials, and Design of Standard (Tenckhoff) and Newer Catheters.

Catheter	Material	No. of cuffs	Cuff material	Segment between cuffs	Intra-abdominal segment	Additional features
 Tenckhoff	Silicone (ID = 2.70)	2	Dacron	Generally straight	Straight or coiled	—
 Missouri Swan neck	Silicone (ID = 2.70)	1 – 2	Dacron	Arcuate 150° – 170°	Straight or coiled	Pre-peritoneal flange
 Cruz	Tecoflex (ID = 3.25)	1 – 2	Dacron	“Pail handle” (two 90° angles on different planes)	Coiled	Uniform, radio opaque line; built-in adaptor
 Toronto-Western	Silicone (ID = 2.70)	1 – 2	Dacron	Generally straight	Straight	Perpendicular discs on intra abdominal segment
 Column disc	Silicone (ID = 2.70)	2	Dacron	One 90° angle long distal cuff	Flat disc	Column disc apposed to the inner abdominal wall

wall and they elicit tissue in-growth on them from the surrounding structures and thus a barrier to bacteria in the pericatheter space is formed as well as a means to prevent the leakage of dialysate.

The incorporation of these Dacron cuffs was a very important advancement in the evolution of the PD catheter. Up to the present time cuffs of Dacron or a similar material is a universal feature in all catheters in use.

The bioincompatibility of Dacron cuffs is ideal for this use. Dacron cuffs are also featured in other implantable devices, such as vascular catheters for hemodialysis (HD) and ports for chemotherapy.

The Function of the Peritoneal Catheter

The main function of this device is to allow a bi-directional flow of dialysate in a consistent manner without requiring extraordinary effort or causing undue discomfort. This flow of dialysate follow simple physical principles [8]. Whether dialysis exchanges are performed manually, as in the case of continuous ambulatory PD (CAPD), or by means of aycler, the flow of dialysate occurs without any assistance from pumps as a result of pressure differences in the system plus the effect

of gravity. Nevertheless, the PD catheter does not work in isolation. Its function is dependent on its design specifications, its implantation site and the configuration of the dialysis system employed to do the exchanges (Table 2).

To better understand the function of the PD catheter it is useful to review some basic aspects of catheter design and manufacture. Most catheters in clinical use employ the same basic principle and are elongated, flexible tubes with multiple ports in the distal or intra-abdominal segment. This segment can be straight or coiled. Coiled catheters with larger numbers of ports have better hydraulic function. The greater number of perforations in the coiled distal end decrease the resistance to flow. The ideal location for the distal segment of the catheter is a free, unencumbered space in the pelvic area, though not necessarily the bottom of the pelvis. The peritoneal cavity, although ideally suited for dialysis, is also occupied by other structures including mesentery, omentum, fallopian tubes, and bowel, all of which can cause PD catheter obstruction. The catheter midportion, normally implanted within the wall of the abdomen, features 1 – 2 Dacron velour cuffs. These cuffs elicit a reaction from surrounding tissue. This results in tissue ingrowth with obliteration of the space between the device and tissue, reducing the potential for dialysate leakage. Both the location of the intramural segment and the orientation of the site where the catheter exits the skin affect the long-term functional life of the catheter [9]. The area where the skin, catheter and the environment interface must be structurally sound and stable. As the catheter exits the skin, it becomes subject to gravitational forces contributed to by its own weight. These forces are more pronounced when the subject is active and/or in an upright posture. The catheter exiting the abdominal wall cephalad or laterally is hard to keep immobilized in order to prevent (or minimize) the stress of

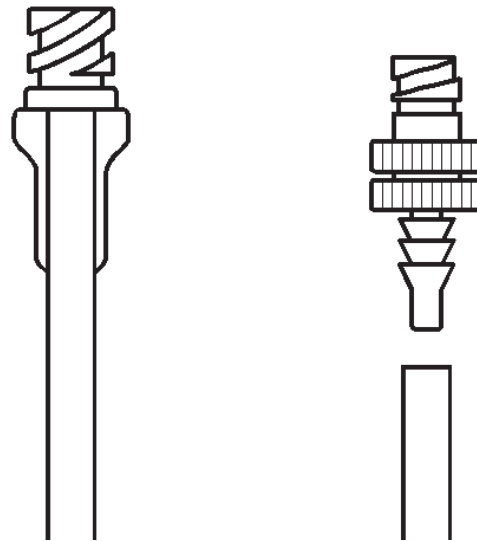


Figure 1. Schematic view of 2 catheters. On the left a catheter with a built-in adapter that preserves the internal diameter throughout. On the right a catheter with a mounted on adapter that creates a stricture at this junction.

gravity and/or tugging during dialysis exchanges. For this reason, some catheters are pre-shaped so that in their unstressed configuration they keep both distal and proximal segments oriented caudally [10, 11]; this facilitates the creation of a caudally-placed exit orifice without increasing the risk of translocating the intra-abdominal segment. Catheter translocation often is caused by the catheter trying to return to its “memory shape”.

The proximal segment of the catheter, which is the visible segment one manipulates during the dialysis exchanges, attaches to the dialysis line by means of an integral adapter or a “mounted-on” adapter (Figure 1). Most mounted-on (conventional) adapters fit inside the catheter distal tip and have smaller lumina, which creates a structure in the dialysate flow path adversely impacting flow rates.

Similarly, the design and specifications of the system employed to perform dialysis ex-

changes influences the function of the catheter. During a typical CAPD exchange the patient sits on a chair with the drain bag on the floor; the bag with fresh dialysate is kept elevated 6–7 feet (2 meters) from the floor to maximize the effect of gravity. For this reason the inflow arm of the Y set is longer than the outflow arm. A shorter non-redundant drain line improves outflow time. As stated above, the main functional quality of the PD catheter is its flow capacity. Dialysate flow during dialysis is governed by simple physics principles, as described by the following equation:

$$Q = P/R$$

where Q = Volume dialysate flow/time, P = Pressure gradient across the end points of the fluid pathway, and R = the hydraulic resistance of the system.

During inflow, the pressure gradient (P) is established by the distance between the top of the column of the dialysate and the distal catheter tip. Conversely, during outflow the P depends on the distance between the intraperitoneal space and the drain bag. As the distance between these points increases, gravity enhances flow velocity. The hydraulic resistance (R) to flow depends largely on the size of the fluid channel. Thus, the design and specifications of the PD sets are major determinants of dialysate flow rates and influence dialysis efficiency.

One can easily manipulate the P/R ratio in order to enhance the flow rate by elevating the dialysate bag maximally during inflow while placing the patient in the supine position (the intra-abdominal pressure is lowest supine and highest sitting). Conversely, during outflow the same is accomplished by lowering the bag maximally and using large capacity drain bags in order to minimize resistance to flow by a filling bag. The pressure gradient changes constantly during the performance of a dialy-

sis exchange, being higher in the early stages of outflow/inflow modes and decreasing as the abdomen and the drain bag fill.

The importance of the PD catheter and dialysis set designs and specifications has been defined only recently. Early studies involving silicone catheters with standard (mounted on) adapter [8] reported dialysate flow rates of 2–2.6 mL/sec. The usual time allocated to perform a 2 L exchange was 20–30 minutes. The advent of PD catheters made out of polyurethane and featuring larger lumina and built-in adapters with the same internal diameter (ID) [11] has spurred interest by investigators and manufactures in dialysate flow dynamics.

In *in vivo* studies polyurethane catheters with built-in adapters 0.130 inches in internal diameter have consistently shown superior flow compared with silicone catheters with an ID = 0.108 inches (Table 3) [12].

The Impact of Catheter Design on Clinical Outcomes

As the number of patients on CAPD has increased world wide, access failure has become one of the major causes of technique failure. Problems with catheter migration, outflow obstruction, inadequate hydraulic function and infection of catheter tunnel and exit orifice present a serious challenge to clinical investigators and the industry.

Over the years a plethora of new catheter designs to solve these problems has emerged [13–21]. However, time has demonstrated that few designs have proven to be superior to the original Tenckhoff catheter design 3 dec-

Table 3. Dialysate Flow Rate According to Catheter/set Design (mL/sec)

	N	Set A	Set B	% Change	P
		(ID = 0.150 in)	(ID = 0.2-in)		
Outflow					
Silicone catheter (ID = .108 in)	10	4.51 ± 0.32	5.57 ± 0.92	23.5	NS
Polyurethane catheter (ID = .130 in)	11	6.12 ± 0.92	9.68 ± 1.89	58.2	0.001
Inflow					
Silicone catheter (ID = .108 in)	10	6.07 ± 0.42	6.51 ± 0.85	7.2	NS
Polyurethane catheter (ID = .130 in)	11	6.94 ± 0.97	9.45 ± 1.69	36.2	0.001

ades ago. Center catheters although in theory of superior design (or more complex) have created their own complications related to: their implantation, especially if the intra-abdominal segment is voluminous; inadequate flow; difficult removal; and infectious complications. As permanently implanted devices increase in size they become a greater problem when infected [14].

The study of these new catheter designs and their own attending complications has nevertheless resulted in a better understanding of the pathophysiology of percutaneous access and spurred interest in this field of investigation.

Interestingly the realization that simplicity in catheter design is associated with better clinical outcomes has led to the development of catheters which incorporate the fundamental elements of the Tenckhoff catheter albeit with some refinements [8, 9, 13].

Swan neck and Cruz catheters (refinements of Tenckhoff design) offer the additional advantage of allowing the creation of a caudally orientated tunnel and exit orifice while maintaining their material configuration, thus reducing the likelihood of exit site and tunnel infections [9, 10].

Implantation Techniques for PD Catheters

Access adequacy is the result of various factors: the PD catheter, the method of implantation, the expertise of the surgeon, the host's reaction to the device, and the care of post-implantation. In spite of refinements in catheter design and methods of implantation, PD access malfunction continues to be a major cause of this modality's failure [16 – 20]. Catheter implantation always requires some sort of "surgical" procedure. The catheter's design and the patient's surgical history and body habitus dictate the extent of the "surgery". Simple devices can be easily implanted using any number of percutaneous methods [9, 22 – 24]. Complex catheters require a more extensive method involving the incision of the parietal peritoneum. Similarly, an "open" procedure or one of the more sophisticated laparoscopic methods of implantation [9] may be indicated in patients with previous abdominal surgeries or in the morbidly obese.

Catheter implantation methods have evolved over the years, as it has been the case

in other surgical procedures. Fiberoptic technology and precise instrumentation have reduced the invasiveness of internal or intracavitary manipulations, decreasing patient discomfort while ensuring efficacy. These methods, championed primarily by non-surgeons, are becoming increasingly popular [9, 22 – 24]. The main relative drawback of these methods is their unsuitability for the implantation of voluminous or complex catheter.

Whether a “conventional” surgical method or any of the percutaneous [9, 22, 23] methods of peritoneal access creation is used, there are basic universal principles that apply in terms of patient preparation, surgical techniques, postoperative care, and catheter conditioning prior to its continuous use.

Patient Preparation

Under ideal circumstances, the catheter implantation is planned electively. Prior to the date of the procedure, the patient is given an explanation of it, and his or her questions are answered. At this time, the implantation site is chosen and marked with water-resistant ink. The site of implantation is chosen taking into consideration the presence of scars, the belt-line location, skin folds, and preserving the site of a future kidney transplant. On the night prior to the procedure, a laxative is administered to evacuate the bowel. An osmotic preparation produces good results with minimal bowel irritation. This method of bowel cleansing facilitates the intra-abdominal positioning of the catheter and lowers the risk of viscus injury (if a percutaneous approach is used). On the day of the procedure, the patient showers with germicidal soap and empties his/her bladder immediately prior to the procedure.

Antibiotic Prophylaxis

Although there are few prospective studies on the effectiveness of transoperative antibiotic prophylaxis on postcatheter implantation infection, data from other clinical situations involving corporeal access and the implantation of devices [25] suggest a role for a dose of antibiotics administered pre or trans-operatively. One dose of a second generation cephalosporin or vancomycin can be used effectively.

Sedation / Anesthesia

Conventional preoperative sedation with meperidine and midazolam, in standard doses is recommended to increase patient comfort. General anesthesia is not necessary for an uncomplicated implantation, especially if one of the percutaneous methods is being used. An exception to this is the case of video laparoscopy with gas insufflation, which requires the patient to be under general anesthesia. One-percent xylocaine with epinephrine produces good anesthesia and hemostasis on skin and subcutaneous tissue. Plain 1% xylocaine is recommended for the dorsal and ventral fasciae during an “open” surgical procedure.

Surgical Implantation Principles

The Implantation Site: Over the years, a shift from the midline approach in favor of a lateral one (paramedial) has taken place [9, 26]. The advantages of positioning the deep



Figure 2. Schematic view of the free position of the PD catheter within the peritoneal space away from the cul de sac. The subcutaneous tunnel is caudally orientated and at least 2.5 cm. Separate the proximal cuff from the exit orifice.

catheter cuff in the body of the rectus abdominal muscle as opposed to the midline are (1) better tissue ingrowth around the cuff due to the richer vascularization of muscular tissue, (2) better structural support for the catheter and, (3) a stronger seal around the catheter, minimizing the risk of dialysate leakage [9, 10]. Regardless of the implantation method used, catheters of simple design ought to be introduced into the peritoneal cavity through a small puncture of the parietal peritoneum. Purse-string sutures around the catheter at the level of the fascia prevent accidental dislodgment of the catheter and dialysate leakage [10, 22].

The Placement of the Intra-abdominal Segment: It is important for adequate catheter function that the intra-abdominal segment be free and in its natural, unstressed configuration within the free peritoneal space. A catheter placed in the cul-de-sac not only will cause discomfort during inflow and outflow, but it will be affected by bowel function (Figure 2).

Intraoperative Testing: The testing of the hydraulic function of the catheter prior to the

tunneling procedure is of great importance. A 1-L dialysis exchange is performed noting the velocity of dialysate inflow and outflow. An obvious advantage of the use of local anesthesia and sedation over general anesthesia is that it allows the patient to tell if the flow of dialysate causes discomfort or pain. Pain, undue discomfort, the awareness of dialysate flow, and less than adequate hydraulic function are indications for catheter repositioning. This is the best time for any necessary adjustment in the placement of the catheter. Catheters that function less than adequately, initially, seldom improve spontaneously – if anything, they get worse. No implantation procedure should be completed without verification of adequate, painless dialysate flow.

The Tunneling Maneuver: Once the catheter has been verified to show optimal function, it is transversed through a subcutaneous tract and emerges at the exit site (an orifice created approximately 2.5 cm from the subcutaneous Dacron cuff). The tunneling is performed using instruments onto which the catheter's proximal segment is connected to minimize tissue trauma as the tunnel is created [10, 22].

The tunneling should be done in a manner that prevents catheter placement in a “stressed” configuration. The caudal orientation of the tunnel places the catheter/skin interface under less stress than if a cephalad or laterally placed tunnel/exit site is created. The catheter will be more stable and less subject to the stresses of gravity and “tugging” of the catheter occurring during repeated catheter handling. Catheters that are permanently bent [10, 11] and dictate the caudal positioning of both the intra-abdominal and proximal segments offer advantages over conventional (straight) catheter, which would have to be tunneled in an unnatural or stressed configuration in order to achieve the same effect. The elimination of the skin at the exit site using a 4 mm punch biopsy helps prevent the invagi-

nation of dermis around the catheter and results in a clean stable exit site. The catheter exit site should be away from skinfolds, so as to be easily accessible.

Surgical Method

The “open” surgical method of catheter implantation is the most commonly used (approximately 80% of catheters are implanted surgically). This method is effective regardless of the catheter design, although, catheters of large volume or complex configurations require to be introduced into the abdominal cavity through an incision in the parietal peritoneum. Otherwise catheters of simple design require a very simple surgical technique illustrated in Figure 3a – 3r.

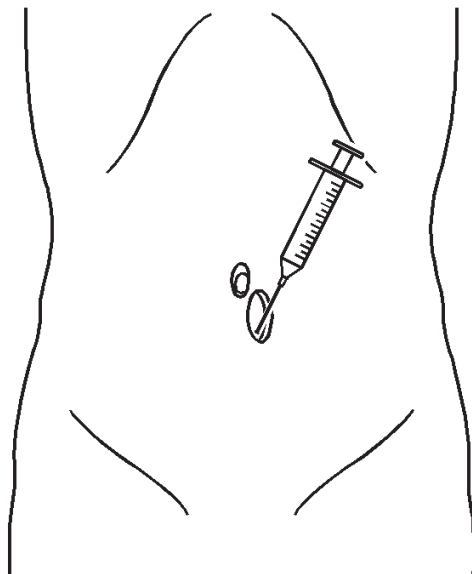


Figure 3a. Surgical technique for a double cuff catheter with built-in adapter. The ideal site of implantation is the paramedial line 2 – 3 cm below the umbilicus. The skin and subcutaneous tissue are infiltrated with 1% xylocaine with epinephrine.

Laparoscopic Techniques

Over the last 2 decades alternative methods of catheter implantation have been developed and refined, utilizing simplified laparoscopic equipment in order to directly visualize the intraperitoneal space where the catheter is positioned [8, 22, 24]. Typically a trocar – cannula wrapped on a disposal sheet is used as a conduit for the sequential introduction of

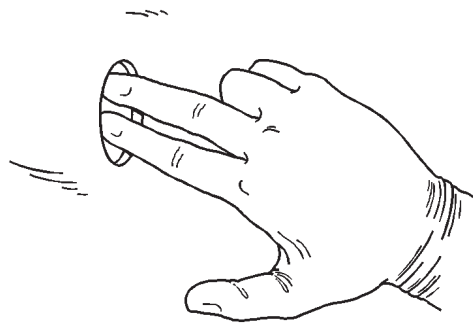


Figure 3b. Surgical technique for a double cuff catheter with built-in adapter. A 5 – 8 cm incision is made as the subcutaneous tissue is dissected with a blunt instrument or electrocautery until the fascia of the anterior rectus muscle is identified.

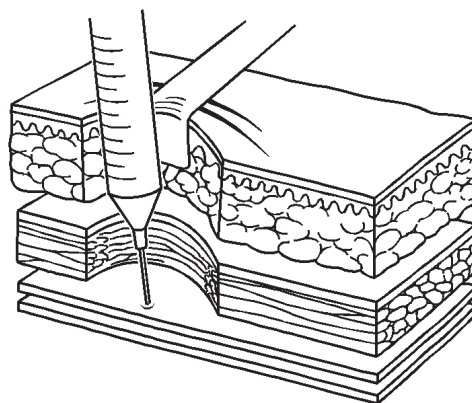


Figure 3c. Surgical technique for a double cuff catheter with built-in adapter. Infiltrate the anterior fascia with 1% xylocaine.

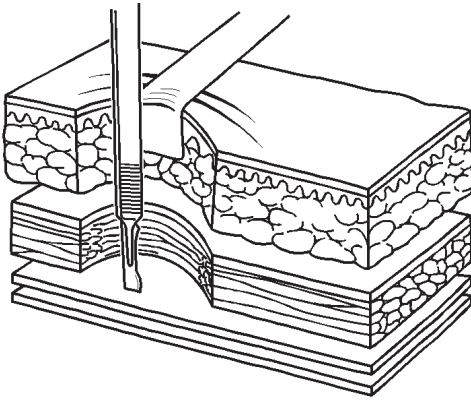


Figure 3d. Surgical technique for a double cuff catheter with built-in adapter. Incise the anterior rectus fascia along the axis of the fibers.

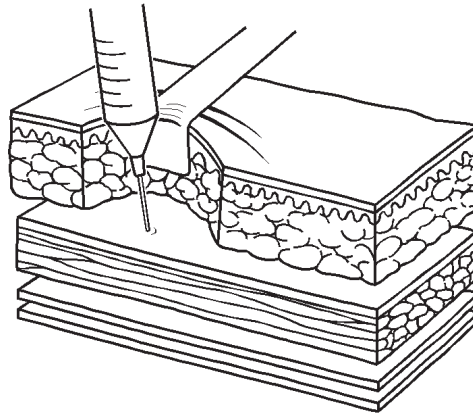


Figure 3f. Surgical technique for a double cuff catheter with built-in adapter. The posterior rectus fascia and parietal peritoneum are then infiltrated with 1% plain xylocaine.

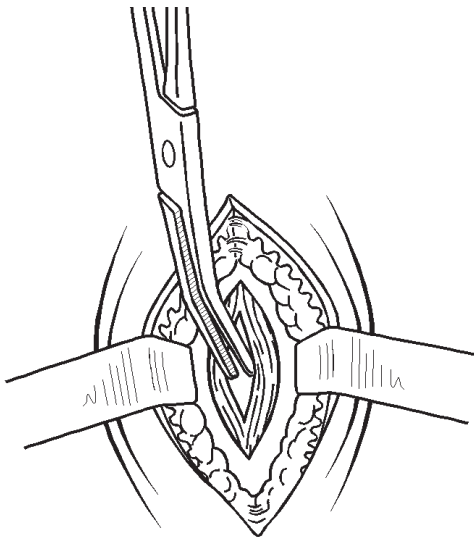


Figure 3e. Surgical technique for a double cuff catheter with built-in adapter. Bluntly separate the rectus muscle fibers along the axis avoiding injury to the epigastric vessels.

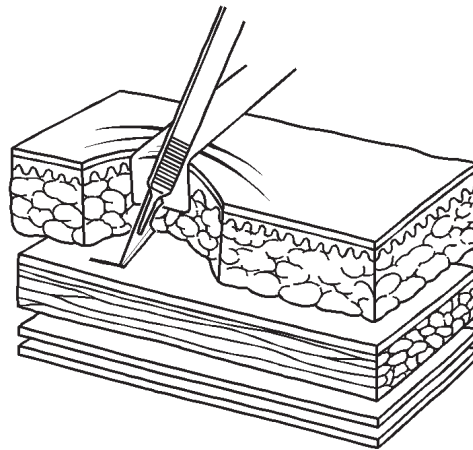


Figure 3g. Surgical technique for a double cuff catheter with built-in adapter. The posterior fascia and parietal peritoneum are then punctured with a number 11 blade or with a muscular clamp to create an orifice through which the catheter can be inserted.

the laparoscope and the catheter into the intraperitoneal space. Compared with the conventional surgical methods simple laparoscopic implantation is very effective and less traumatic.

As laparoscopic methods are refined this technology has also been employed to manage malfunctioning catheters and to carry out epiploxy of the greater omentum in cases of obstruction caused by omental wrapping [27].

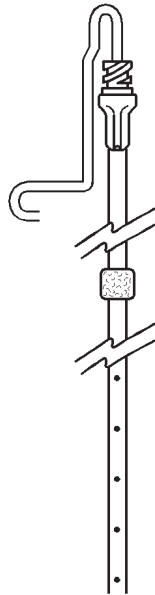


Figure 3h. Surgical technique for a double cuff catheter with built-in adapter. The catheter, which has been soaked in saline and has had the air removed from the cuffs is mounted on a stylet. Be careful that it is not turned on its axis.

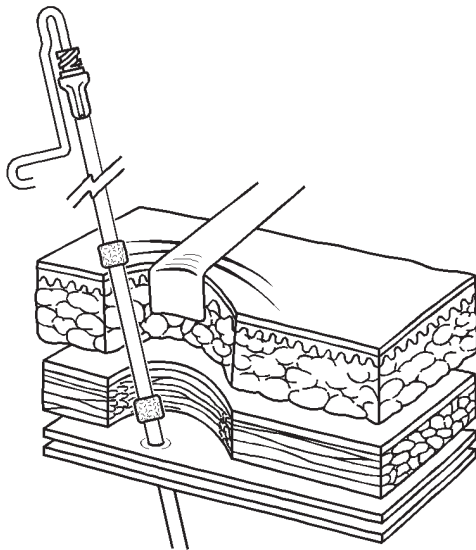


Figure 3i. Surgical technique for a double cuff catheter with built-in adapter. Insert catheter through the peritoneal puncture hole or incision withdrawing the stylet gradually as the catheter advances. The catheter is advanced toward the pelvis.

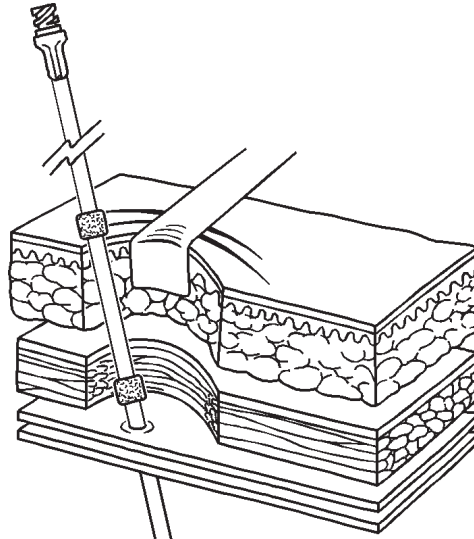


Figure 3j. Surgical technique for a double cuff catheter with built-in adapter. A purse string suture is used to close the peritoneal orifice at the level immediately distal to the distal cuff.

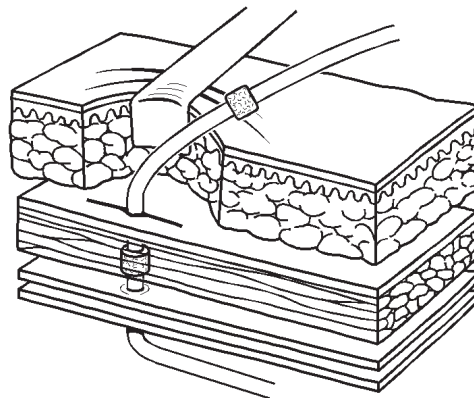


Figure 3k. Surgical technique for a double cuff catheter with built-in adapter. In doing so, the cuff will rest within the body of the rectus abdominal muscle.

Delayed Catheter Exteriorization

This recently introduced catheter implantation method incorporates into an “open” sur-

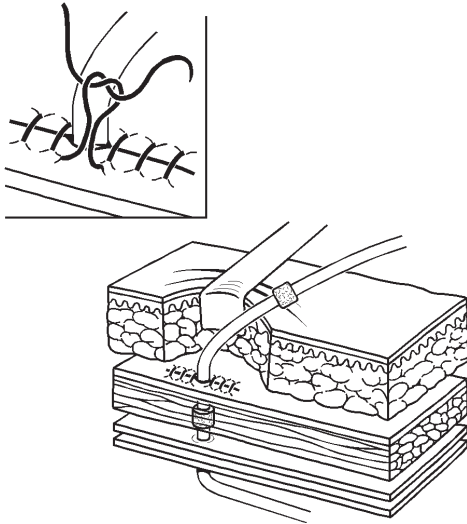


Figure 3l. Surgical technique for a double cuff catheter with built-in adapter. The anterior rectus fascia is then sutured with interrupted absorbable sutures. Once again, care has to be taken that the distal cuff be well within the muscle fibers. A purse string suture using a 0 Vicryl is then made to add security to the catheter. The catheter can now be tested by irrigation with a large syringe and saline solution.

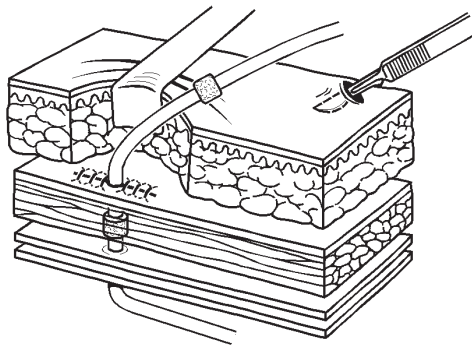


Figure 3m. Surgical technique for a double cuff catheter with built-in adapter. The exit site is preferably 3 – 4 cm away from the subcutaneous cuff. The skin site is anesthetized and a 1.5 – 2 cm stab wound is made toward the primary incision.

gical method the positioning or embedding of the catheter external segment in a subcutaneous pouch for a period of 4 – 8 weeks, making

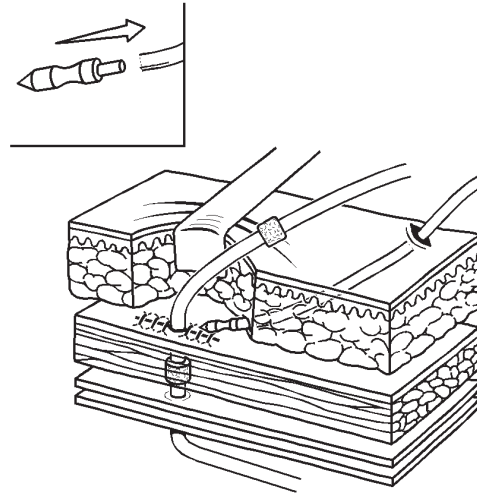


Figure 3n. Surgical technique for a double cuff catheter with built-in adapter. The tunneling device is then advanced through the exit site in the direction of the primary incision.

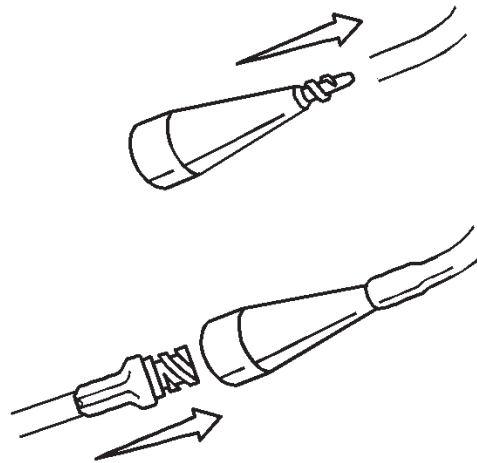


Figure 3o. Surgical technique for a double cuff catheter with built-in adapter. Its tip is removed and replaced by the socket for the catheter adapter.

a complete wound closure with a secondary creation of an exit site. The aim of this surgical method is the reduction of infectious complication, presumably the result of the introduction of bacteria along the tunnel during the post-operative period before tissue in-growth

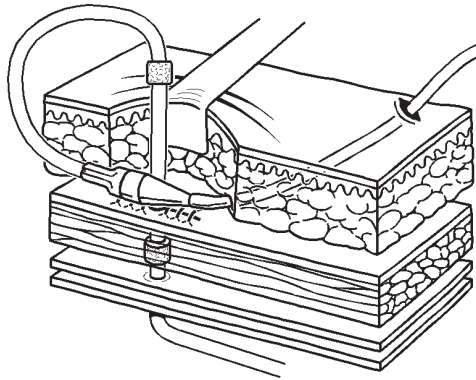


Figure 3p. Surgical technique for a double cuff catheter with built-in adapter. The device and connected catheter are then pulled gently through the exit site in the least traumatic manner.

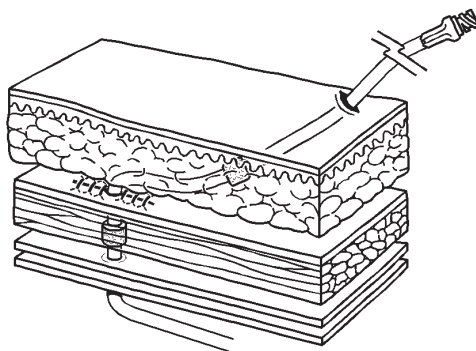


Figure 3q. Surgical technique for a double cuff catheter with built-in adapter. It is recommended to attach an extension set at this time and flush with dialysis or saline solution. The primary incision is sutured in layers.

takes place. By delaying the creation of the exit site, presumably a better bacteriologic barrier between exit site and peritoneum takes place [28]. Some disadvantages of this method have included the inability to initiate or prepare for PD in due time, delayed wound healing, seromas, subcutaneous hematomas, serious obstruction by fibrin thrombi and omental obstruction found at the time of initiation of dialysis [29].

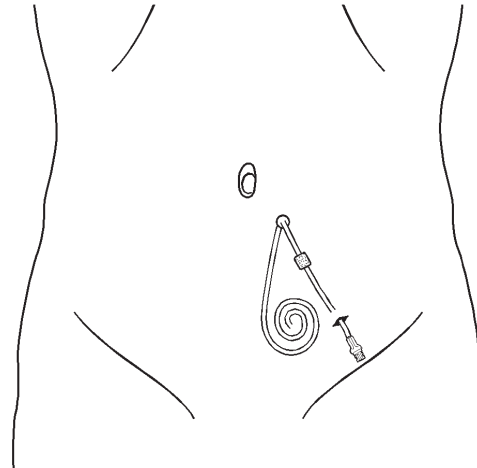


Figure 3r. Surgical technique for a double cuff catheter with built-in adapter. The catheter is now ready for use.

The End Result

Whether an “open” surgical method or any of the laparoscopic methods of catheter implantation is chosen, the ideal end result is an efficient unincumbering, easily concealed catheter that functions in harmony with the patient’s peritoneal cavity and the dialysis system chosen. The implanters main aim is thus the creation of a stable interface between catheter, skin and the environment as Figure 3 illustrates.

The Care and Maintenance of the PD Catheter

The care and maintenance of the PD catheter (or lack thereof) are as important as its material design or method of implantation in determining dialysis technique survival.

The maintenance requirements of the PD catheter are largely dependent on its design and the materials used for its manufacture.

The catheters most widely used today feature a permanent bend and a simple (either coiled or straight) intra-abdominal segment. They are manufactured from 2 basic materials, which differ in their physical properties:

Silicone rubber: Silicone catheters have thick walls are thermoset and cannot be bonded to other materials. They have provided adequate function for > 25 years.

Polyurethanes: Polyurethane catheters offer some advantages over silicone catheters in terms of thermoplasticity, tensile strength and their ability to bond to other materials. Thus they can feature a permanently attached adapter. Polyurethane catheters have larger lumina and high flow rates. Polyurethane, however, requires a little extra care as it is negatively affected by high temperatures, certain solvents, such as those contained in the base of topical antibiotic preparation such as mupuricin and prolonged exposure to concentrated chlorinated compounds and hydrogen peroxide [30, 31].

All catheters require basic precautions including the avoidance of using scissors, blades or clamps with either teeth or sharp edges, which may damage the catheter or adapter.

Post-operative Catheter Care

In order to promote wound healing and tissue ingrowth on the catheter cuffs so that a bacterial barrier develops, it is recommended that the catheter be immobilized and the

wound and exit orifice be covered by a surgical dressing for 3 – 7 days. Thereafter, daily cleansing of the exit orifice with povidone iodine followed by sterile dressing is continued for 6 weeks.

After 6 weeks when catheter implantation should be well established, the exit site care can be reduced to washing with soap and water (while showering) followed by thorough drying (a hair dryer at low setting can be very effective).

From this point on the use of gauze dressing is optional. The preservation of the pericatheter skin integrity is very important and use of the following should be avoided: iodine compounds, alcohol, hydrogen peroxide, adhesives, powders, topical antibiotics, and steroid creams.

Catheter Conditioning

Break-in procedure. The rationale of break-in is to maintain catheter patency, especially in the presence of post-surgical bleeding during wound healing and tissue ingrowth between implantation and the onset of dialysis.

Catheters implanted through peritoneal puncture, as opposed to an incision, can generally be utilized following implantation without a break-in period, especially if reinforced by a purse string suture at the level of the distal cuff. However, it is preferable to wait at least 2 weeks to minimize the risk of pericatheter leak.

During this period, patient activity and intra-abdominal pressure should be kept at a minimum, and coughing, lifting and straining while defecating should be avoided.

Flushing Methods

Three main methods may be used for flushing:

- After an initial set of rapid exchanges a two-liter bag of dialysate with 2500 – 5000 units of heparin is connected to the patient followed by infusion of 25 – 50 mL of solution by opening the line every 2 – 3 hours while counting to 5. This small volume of dialysate will clear the catheter of fibrin and blood and will be absorbed by the peritoneal lymphatics. The solution bag can then be replaced every 3 – 4 days by the nursing staff.
- After an initial set of rapid exchanges with heparinized dialysate (2500 μ L) a rapid exchange is performed every other day in a similar manner leaving 300 – 500 mL in the abdominal cavity each time.
- If the patient is in need of dialysis immediately after the catheter implantation, manual or cycle assisted dialysis can be instituted using small dialysate volumes (1000 mL of heparinized dialysate) during 48 – 72 hours while the patient remains recumbent. Either of the above protocols can then be resumed.

Care of the Catheter/Adaptor Junction

Catheters mounted in conventional adapters often show wear and tear of their end at the adapter site resulting in fissures, leaks and accidental disconnections when they become incompetent. The use of extension segments that can be replaced every few months if damaged by clamps, accidental clipping or cutting, is recommended to prolong the life of the catheter.

Catheter-related Complications

Most mechanical or non-infectious complications can be avoided or minimized with proper implantation technique and catheter maintenance in combination with a judicious dialysis regime.

Immediate post-operative hemoperitoneum, dialysate leakage and catheter obstruction are prime examples of improper surgical technique. The risk of herniation can be substantially decreased by avoiding the use of large volume exchanges in favor of more frequent exchanges of lesser volume. Large intraperitoneal volumes should be only employed when the patient is in the supine position. To this effect the combination of cyclor dialysis at night and small diurnal manual exchanges is ideal. Patients should refrain from activities that greatly increases the intra-abdominal pressure such as vigorous exercise or weight lifting. Physical fitness and any method that increases that strength of abdominal musculature should be encouraged. If patients are keen on vigorous training, they can be taught to exercise with a near-empty abdomen.

Care of Catheter-related Complications

Dialysate Leakage

Dialysate leakage through the space between the catheter and the abdominal wall occurs more often if the parietal peritoneum was incised during the catheter implantation,

or when there is failure of the tissue surrounding the distal cuff to grow into it. The incomplete obliteration of this pericatheter space by tissue ingrowth coupled with sudden increase in the intraabdominal pressure causes the dialysate to leak through the tunnel either externally or through the preperitoneal space into the subcutaneous tissue of the abdominal wall, the scrotum in the male or the labia in the female. Delayed wound healing caused by malnutrition or treatment with corticosteroids may predispose some patients to this complication.

Dialysate leakage tends to occur early in the postoperative period. Failure to place a purse string suture around the catheter as it exits the rectus fascia may also cause this complication. Occasionally patients with severe bouts of coughing or who experience sustained elevation of intra-abdominal pressure, as in weight lifting, may experience dialysate leakage.

Rarely dialysate leakage occurs through other weak points in the abdominal wall such as sites of previous laparoscopic procedures, surgical wounds or previous catheter implantation sites and in this instance surgical repairs of the abdominal wall may be necessary. Otherwise, for early postoperative leakage the management includes discontinuation of PD, generally for 3–4 weeks or as long as it takes for the pericatheter space to obliterate. During this period the patient should be placed on HD. In extreme situations where HD is not possible cyclo-assisted dialysis can be instituted using small volume exchanges while the patient remains in the recumbent position.

Regular dialysis can be instituted when the patient can ambulate for 4 hours with at least 1L dialysate in the abdomen without experiencing leakage.

Catheter Cuff Erosion / Extrusion

This late catheter complication is most often the result of a combination of factors: improper position of the proximal cuff (less than 2.5 cm away from the exit orifice), the effects of tugging on the catheter during the dialysis exchanges and patient weight loss with a decrease in the thickness of the subcutaneous tissue around the catheter. Patients generally note increasing irritation and pain at the exit site with the gradual emergence of the catheter cuff through the exit orifice. Once this problem is identified, the elective shaving of the cuff using a number 11 surgical blade, sterile technique, and one dose of prophylactic antibiotics can salvage the catheter if no other problems are present such as infection of the catheter tunnel. Following the shaving, liquid silicone can be used to coat the site where the cuff was before the positioning of the catheter in its usual space.

Catheter Obstruction by Fibrin Thrombi

This complication occurs most often in the early postoperative period particularly if bleeding occurs during the implantation and failure to irrigate the catheter on a regular basis before its continued use.

Catheter obstruction caused by debris or coagulation of transudate can occur also if the abdominal cavity is left dry following the implantation, as occurs with the method of delayed exteriorization of catheters [29]. Vigorous manual irrigation using a large syringe usually solves the problem. In more stubborn

cases the instillation of urokinase can correct the problem: using sterile technique, the catheter is attached to a line through which 10,000 units in 100 mL of saline solution are dripped over one hour. After 1 – 2 hours the manual irrigation can be tried again. Rarely severe obstruction of catheter fibrin can be refractory to all maneuvers forcing catheter replacement.

Catheter Obstruction by Omentum Wrapping

The catheter as a foreign body is often entrapped by omental tissue causing it to obstruct. On rare occasions other intra-abdominal structures can obstruct the catheter such as the appendix and fallopian tubes [32 – 34]. This complication can occur early or late and has a typical presentation characterized by a variable period (weeks, months or years) of adequate hydraulic functions followed by increasing signs of flow restriction especially during outflow until there is total cessation of flow. This process can occur over days or even weeks and is refractory to all irrigating maneuvers and the use of heparin and/or urokinase. There is usually radiologic evidence of catheter displacement.

The most effective method to deal with this complication is to perform a partial omentectomy. A laparectomy using a midline incision that does not involve the intramural catheter segment is performed. If omental trapping is confirmed excision of the intra-abdominal segment and partial omentotomy are done without disturbing tunnel or exit site. After wound closure, PD albeit with small volumes can be resumed without problems. Laparoscopic epiploxy of the greater omentum has also been used in recent years to correct catheter malfunction by omental wrapping.

Catheter Migration

Catheter migration occurs less frequently following the advent of preshaved (permanently bent) catheters. Catheter migration is usually the result of improper implantation of silicone (thermoset) catheter as they try to regain their natural unstressed configuration. These are anecdotal reports of successful retrieval of migrated catheters using laparoscopy or guide wire manipulation under fluoroscopy [27, 34]. The only effective long-term solution of the problem is catheter replacement.

Access Efficiency and Dialysis Adequacy

As the adequacy issues of PD have become better understood it has become apparent that “access adequacy” is a critical factor in the dialysis adequacy equation. Access adequacy is determined by the interplay of the catheter design and specification and the degree of stability of the catheter, skin and environment interface (which is largely determined by the implantation method and subsequent care).

Properly implanted modern catheters have the potential to increase the success and efficiency of PD by consistently providing optimal dialysate flow without requiring special care or effort or interfering with patient comfort.

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