Overview of Catheter Choices and Implantation Techniques

5

Pierpaolo Di Cocco, Edwina A. Brown, Vassilios E. Papalois, and Frank J.M.F. Dor

Decision-Making Algorithm for Peritoneal Dialysis (Patient-Centered)

The selection of dialysis modality is of great importance in planning a successful transition to renal replacement therapy in patients approaching end stage renal disease (ESRD). It is increasingly recognised that individuals, institutions, governments, and specialty societies may direct and subliminally influence the patient's selection/choice of dialysis modality. The most visible and widespread effort in this regard is the CMS (Center for Medicare and Medicaid Services) FISTULA FIRST National Vascular Access Improvement Initiative [1, 2]. Similarly, the International Society for Peritoneal Dialysis is stressing the underutilization of the peritoneal dialysis modality, especially in the Western societies [3].

Rather than emphasizing the doctrine of one modality fitting all, it is ethically and morally a better model to consider a patient driven approach, keeping in mind quality of life, outcomes and costs. Consequently, the decision-making algorithm for two similar patients may vary, based on individual circumstances.

This chapter describes the types of peritoneal dialysis catheters and implantation techniques applied for peritoneal dialysis, technical considerations, and some of the related surgical complications.

Anatomy

A basic knowledge of the anatomy of the anterior abdominal wall and peritoneal cavity is necessary for a better understanding of the various techniques of catheter placement. The skin of the anterior abdominal wall is of moderate thickness and is relatively fixed on the underlying fascia and muscle layers (Fig. 5.1). The innervation of skin, fascia, muscles and parietal peritoneum of the anterior abdominal wall is segmental, mainly from the anterior primary rami of spinal nerves T6 to L1.

The main muscles of the abdominal wall are the rectus abdominis and pyramidalis muscles, which are anterior; the external and internal oblique muscles and the transversus abdominis muscle, which are lateral (Fig. 5.2). The fibers of the rectus run vertically; those of the external oblique muscle run inferior and anterior; those of the internal oblique muscle run superior and anterior, and those of the

P. Di Cocco, MD • E.A. Brown, MD
V.E. Papalois, MD • F.J.M.F. Dor, MD (✉)
West London Renal and Transplant Centre, Imperial College Healthcare NHS Trust, Hammersmith Hospital, 4th Floor Hammersmith House, Du Cane Road, London W12 0HS, UK
e-mail: Pierpaolo.DiCocco@imperial.nhs.uk; Edwina.Brown@imperial.nhs.uk; Vassilios.Papalois@imperial.nhs.uk; Frank.dor@imperial.nhs.uk

S. Haggerty (ed.), *Surgical Aspects of Peritoneal Dialysis*, DOI 10.1007/978-3-319-52821-2_5

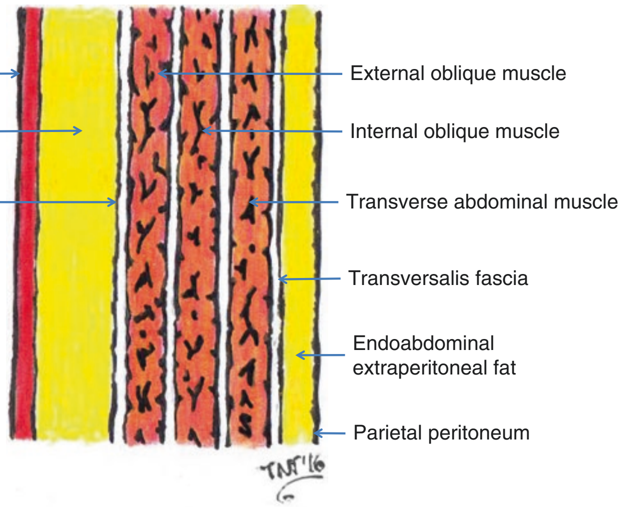

Fig. 5.1 Section of the abdominal wall – coronal plane

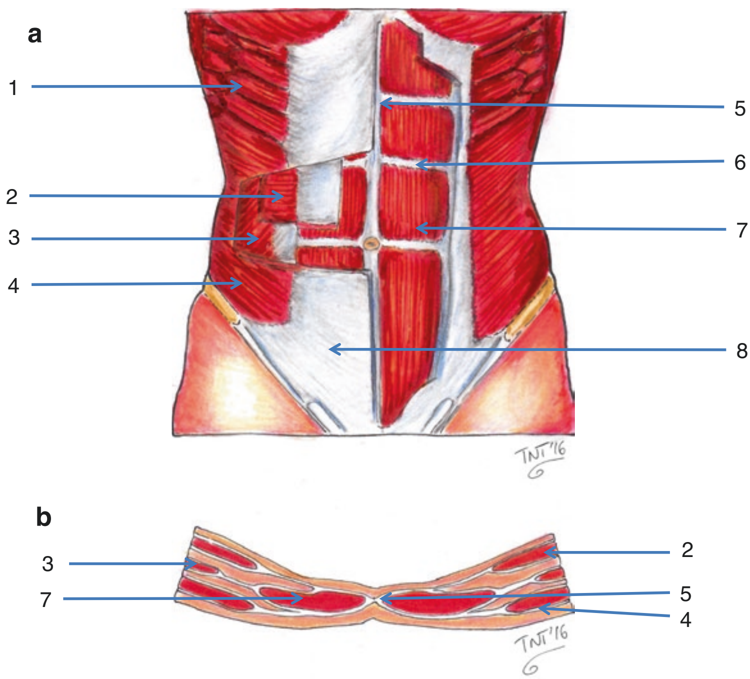

Fig. 5.2 Frontal (**a**) and transverse (**b**) planes of the abdominal wall muscles – *1* Serratus anterior; *2* Transversus abdominis; *3* Internal oblique; *4* External oblique; *5* Linea alba; *6* Tendinous intersection; *7* Rectus abdominis; *8* Aponeurosis of the external oblique

transversus run transversely. The major vessels and nerves pass downward and medially in the neurovascular plane, between the transversus abdominis and the internal oblique muscles (Fig. 5.3). Supplying the rectus muscle and firmly adherent to its posterior surface are the epigastric vessels. These could be potentially damaged, particularly during a lateral approach for surgical catheter insertion either with open or laparoscopic approaches. The rectus sheath appears as an elliptical tube with a strong anterior wall. The weaker posterior wall only extends to just below the level of the umbilicus.

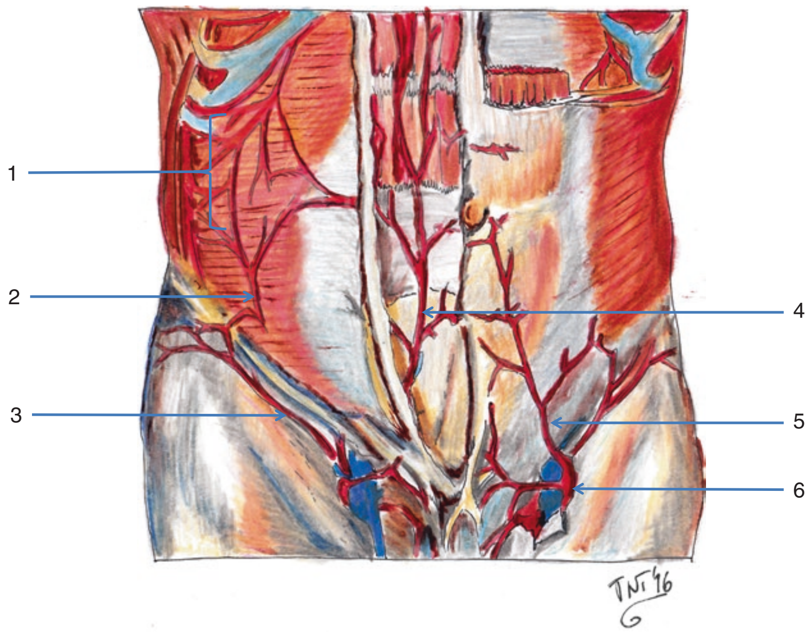

Fig. 5.3 Arterial anatomy of the abdominal wall – to be considered during PD catheter insertion – *1* Anastomoses with lower intercostal, subcostal and lumbar arteries; *2* Ascending branch of the deep circumflex artery; *3* Superficial circumflex iliac artery; *4* Inferior epigastric artery; *5* Superficial epigastric artery; *6* Femoral artery

Types of Peritoneal Catheters

(a) **Acute peritoneal dialysis catheters**

All catheters used for acute peritoneal dialysis are straight or slightly curved, relatively rigid tubing with numerous side holes at the distal end without any protective cuff. The implantation can be carried out with Seldinger percutaneous, open or laparoscopic insertion techniques. Acute peritoneal dialysis is still used in the management of acute and chronic renal failure in many developing countries [4, 5], where costs are a major limitation. In this setting, it is usually placed at the bedside under local anaesthesia, and catheters are used immediately after implantation. The absence of cuffs, a protection against bacterial migration, makes the incidence of peritonitis prohibitively high beyond 3 days of use; if extended dialysis is necessary the acute catheters are periodically replaced.

(b) **Chronic peritoneal dialysis catheters**

There are several types of catheters for chronic peritoneal dialysis; the basic structure is the same with an intraperitoneal portion, one or two cuffs, an inter-cuff segment and an external portion (Table 5.1). They are constructed from silicone rubber or polyurethane and are flexible, and atraumatic to the bowel. Catheters are available with barium impregnated either throughout or as a radiopaque stripe to assist in the radiologic localization of the intra-abdominal section. The silicone rubber or polyurethane surface promotes development of squamous epithelium in the subcutaneous tunnel around the catheter, at the exit site and within the abdominal wall. The presence of this epithelium increases resistance to bacterial penetration of the tissue near the skin exit and peritoneal entry sites. The Dacron cuffs provoke a local inflammatory response with fibrosis, which gives stability to the catheter and prevents bacterial migration from the skin surface into the subcutaneous tunnel and peritoneal cavity.

The intraperitoneal segment has multiple 0.5 mm perforations in the terminal part. Several modifications have been made to the intraperitoneal portion and to the tip of the catheters, with

Table 5.1 Characteristics of peritoneal dialysis catheters

Catheter type	Material	Cuffs	Shape of intra-abdominal segment	Inter-cuff shape	Characteristics
Tenkhoff catheters	Silicone	1–2	Straight/coiled	Straight/ Swan-Neck	
Toronto Western Hospital (TWH) or Oreopoulos-Zellerman catheter	Silicone	2	Straight	Straight	Dacron disc plus a silicone rubber bead (intraperitoneal segment)
Swan-Neck Missouri catheters	Silicone	1–2	Straight/ coiled[a]	Swan-Neck (bend 180° arc angle)	Bead and flange (intraperitoneal segment)
Pail-Handle (Cruz) catheter	Polyurethane	2	Coiled	Two bends (90° arc angle)	
Presternal Swan-Neck peritoneal catheter	Silicone	1–2	Straight/coiled	Arcuate inter-cuff shape	Titanium connector (between proximal and distal-end)
Moncrief-Papovich catheter	Silicone	2	Coiled	Arcuate inter-cuff shape	Larger external cuff (2.5 cm)
Ash (Advantage) catheter	Silicone	2	Straight		T-shaped

[a]Because in several patients infusion pain occurred due to a “jet effect” and/or tip pressure on the peritoneum, the intraperitoneal segment of the catheters, was modified replacing a straight segment with a coiled one

the aim of obtaining an unrestricted flow of dialysate to and from the peritoneal cavity. This flow is most efficient if the catheter tip lies deep within the pelvis (also changes for dislocation/migration are less when placed deep in the pelvis). Catheter design and insertion techniques aim at the prevention of one- or two-way obstruction, tip displacement from the pelvis, common causes of catheter malfunction. Different catheter lengths are available for every patient size.

- Straight and coiled Tenkhoff catheters
- Toronto Western Hospital (TWH) or Oreopoulos-Zellerman catheter
- Straight and coiled Swan-Neck Missouri catheters
- Pail-Handle (Cruz) catheter
- Presternal Swan-Neck peritoneal catheter
- Moncrief-Papovich catheter
- Ash (Advantage) catheter
- Catheters designed for continuous flow peritoneal dialysis (CFPD)

Straight and Coiled Tenkhoff Catheters

The Tenckhoff catheter, first catheter with a widespread clinical use, is now available in different lengths, shapes and number of Dacron cuffs. It remains the most commonly used and the standard for comparison with other catheters. The catheter consists of a silicone rubber tube, bonded to one or two 1 cm cuffs. A barium-impregnated radiopaque strip assists in its radiological visualization. The intraperitoneal portion varies in length from 6.5 to 19.5 cm, with perforations (0.5 mm) in the terminal 2.5–9.5 cm [4, 6]. The intraperitoneal tip is in two shapes, coiled and straight [5].

Toronto Western Hospital (TWH) or Oreopoulos-Zellerman Catheter

The Toronto Western Hospital (TWH) or Oreopoulos-Zellerman catheter is a modified version of the Tenckhoff catheter [7]. The TWH1 and TWH2 are the two types available. Both catheter types have two flat silicone rubber discs attached to the catheter tip with the aim to be more stable in the pelvis. TWH2 has an additional modification consisting of a Dacron disc plus a silicone rubber bead in series with the preperitoneal cuff. The incorporation of a disc just superficial to the peritoneal closure is an attempt to prevent late dialysate increasing the area of peritoneal sealing. The catheter has two cuffs with a straight intra-abdominal and inter-cuff shape.

Straight and Coiled Swan-Neck Missouri Catheters

The Swan-Neck Missouri catheters are so called because of the permanent bend of the inter-cuff segment [8]. The inter-cuff shape, Swan-Neck, gives to the intraperitoneal and extraperitoneal segments an unforced downward direction. Several modifications have been described such as the number of cuffs (1 or 2), the distance between cuffs, the arc angle bend, increased from 80° to 180°, and the replacement of a straight intraperitoneal segment with a coiled one due to infusion pain ("jet effect" and/or tip pressure) on the peritoneum, occurred in several patients [9].

Pail-Handle (Cruz) Catheter

This catheter (polyurethane) has two right-angle bends of the inter-cuff segment: one to direct the intraperitoneal portion parallel to the parietal peritoneum and one to direct the subcutaneous portion towards the skin exit site. There are two cuffs and a coiled intra-abdominal segment. A single centre case series on 63 Pail-Handle catheters surgically implanted in 57 consecutive patients with a 5 year follow up, found a cumulative catheter survival rate of 80.8% at 12 months, 62.3% at 24 months and 48.1% at 51 months. An adverse outcome described in the study was related to the catheter adapter that caused large exit site wounds, predisposed to infection and catheter loss [10].

Presternal Swan-Neck Peritoneal Catheter

The swan neck pre-sternal catheter (silicon rubber) is composed of two flexible tubes joined by a titanium connector at the time of implantation. The exit site is located in the parasternal area. The catheter located on the chest was designed to reduce the incidence of exit site infections. The tube is bonded to two cuffs, and has a permanent bent (arc angle of 180°) of the inter-cuff segment (swan-neck). Both tubes have a radiopaque stripe that helps to achieve proper alignment of the tube during insertion and to facilitate radiological visualization of the intraperitoneal segment [11, 12].

Moncrief-Papovich Catheter

This catheter (silicone rubber) has several important structural changes compared to the Tenckhoff catheter. The structural changes are: a coiled internal segment, an arcuate bend in the subcutaneous segment similar to the swan-neck Missouri catheter and two Dacron cuffs. The external cuff is elongated from 1 to 2.5 cm. The catheter after implantation is locked with 1000 U of heparin, and the external segment is buried subcutaneously for a period of 4–8 weeks or longer to allow tissue ingrowth into the external cuff in a sterile environment. Subsequently, a small incision is made in the skin through which the external segment of the catheter is brought out [13, 14].

Ash (Advantage) Catheter

The Advantage catheter contains a straight portion that is held adjacent to the parietal peritoneum assuring a stable position, without extrusion of the deep cuff or exit site erosion. The intraperitoneal portion contains a short, perpendicular segment connected to two limbs with external grooves (flutes) to carry fluid into the catheter from the upper and lower abdomen. Due to the apposition of the grooved portion of this catheter against the parietal peritoneum, and the T shape of the catheter, the deep cuff of this catheter is fixed in position, and outward migration of the catheter is very unlikely. Based on the case series described by Ash, the placement of this type of catheter in 18 patients with 4 years of follow-up resulted in the absence of exit site erosion/infection, incisional hernia (peri-catheter) or leaks [15].

Catheters Designed for Continuous Flow Peritoneal Dialysis (CFPD)

Shinaberger and coll. [16], first described this technique in 1965, with the insertion of two peritoneal catheters at opposite sites of the peritoneal cavity. Other groups described this particular technique with mixed success [17–20]. A catheter for CFPD must provide separate conduits for infusing and draining the dialysate into and out of the peritoneal cavity at a high flow rate (100–250 mL/min) with good mixing of the peritoneal solution and minimal streaming and recirculation. The catheter should also be cosmetically acceptable (small diameter, minimal bulk), easy to implant and remove, biocompatible, reliable, and safe.

The simplest devices consist of two straight or curled barrels in a double-D or double-O configuration [21, 22]. The inflow barrel is shorter, and the drain barrel is longer and located in the most dependent pelvic area. Modifications to this basic design include the addition of discs placed in the distal intraperitoneal segment of the catheter to diffuse the inflow stream of dialysate and to improve mixing [23]. A recently introduced design describes a double-lumen catheter with maximum separation of the intraperitoneal limbs to minimize recirculation [24]. It consists of two tubes bonded together as they pass through the abdominal wall and into the peritoneum. The tubes once again separate intraperitoneally by 180° to form a double J, the cranial segment is shorter than the caudal, and both terminate with a fluted end.

Ash and coll. designed for this purpose a catheter with a T shaped configuration in order to maximally separates the tips of the double lumen [25].

Ronco and coll. designed a novel catheter for CFPD equipped with a thin walled silicone diffuser used to infuse the dialysate into the peritoneum. The holes on the round-tapered diffuser are positioned to allow dialysate to perpendicularly exit 360° from the diffuser, thereby reducing trauma to the peritoneal walls and allowing the dialysate to mix into the peritoneum. The fluid is then drained through the second lumen, whose tip is positioned in the lower pelvis [26].

Critical Comparison of Catheter Design

Despite all the different options, most programs limit their experience with one or two catheter types, making difficult a critical comparison. For simplicity and based on studies present in literature, the discussion on which catheter type offers better results focused mainly on the number of cuffs, single versus double, the configuration of the intraperitoneal portion, straight versus coiled, and of the inter-cuff shape, straight versus Swan-Neck. Lewis and coll. carried out a prospective randomized controlled study that favoured the double cuff over the single cuff Tenckhoff catheters, in terms of survival, time to the first peritonitis episode, and number of exit site infections [27]. Previous ISPD consensus opinion also supported the choice of double cuff Tenckhoff catheters [28]. However, Eklund and coll. in a prospective randomized controlled study found no differences in the number of peritonitis episodes, exit site infections, or in catheter survival between single and double cuff Tenckhoff catheters [29]. As mentioned earlier in the chapter, coiled catheters (intra-peritoneal segment) have been developed in order to achieve less infusion/pressure pain (“jet effect”), better flow, less catheter-related complications such as migration and omental wrapping. These theoretical advantages have been substantiated by some authors in randomised controlled trials [30–32], but not confirmed in two more recent meta-analyses [33, 34]. The meta-analysis conducted by Xie J and coll. suggested that coiled catheters might be more prone to migration and resultant dysfunction [33]. A more recent meta-analysis by Hagen and coll., including more studies and with the following outcomes of interest (catheter survival, drainage dysfunction, migration, leakage, exit-site infections, peritonitis, and catheter removal), found no differences when comparing straight versus swan neck and single versus double-cuffed catheters. Comparison of straight versus coiled-tip catheters demonstrated that survival was significantly different in favour of straight catheters (hazard ratio 2.05; confidence interval 1.10–3.79, $P = 0.02$). The conclusion of the authors was that for surgically inserted (open and laparoscopic) catheters, the removal rate and survival at 1 year were significantly in favour of straight catheters [34].

In our experience we primarily use double cuff Tenckhoff catheters, both straight and coiled (intraperitoneal portion) and with straight inter-cuff shape. **When critically comparing the different catheters we have to bear in mind that the most important aspect of preventing mechanical complications is probably attention to detail and the operative insertion technique used** [35].

Chronic Catheter Placement Procedures

Peritoneal dialysis catheters may be placed via a percutaneous, a laparoscopic, or an open surgical route. Open surgical and laparoscopic techniques are the most commonly performed worldwide. According to American data, the laparoscopic technique is now the most commonly used, compared to all other techniques [36].

(a) Percutaneous technique
(b) Peritoneoscopic technique
(c) Open surgical technique
(d) Laparoscopic technique

Seldinger Percutaneous Technique

First described in 1968 by Tenckhoff and Schechter, it is a percutaneous method of catheter placement. The authors reported a high incidence of catheter migration resulting in failure rates up to 65% at 2 years and risk of bowel or vessel injury [4]. Several other reports have shown adequate results, with dysfunction and leak rates below 7% [37–40] and a bowel perforation risk of 1–2% [38, 41]. Zappacosta et al. reserved the percutaneous catheter placement only in patients with no previous abdominal surgery, in view of the high risk of bowel perforation in presence of adhesions [37]. Aksu and coll. achieved excellent results in a pediatric population (108 peritoneal catheters percutaneously placed in 93 pediatric patients) with an overall incidence of catheter dysfunction of 14% over 10-year period and no cases of bowel perforation [42]. Varughese and coll. highlighted that the percutaneous insertion is now preferred in developing countries where costs play a major role [43]. Advantages and disadvantages of this technique are presented in the Table 5.2.

Technical Aspects

Percutaneous placement of peritoneal dialysis catheters, under local anaesthesia, uses a guidewire and a peel-away sheath applying the Seldinger technique.

Table 5.2 Pros and cons of percutaneous insertion

Pros	Cons
Procedure under local anaesthesia	Not all types of catheters can be inserted
Small incision (low risk of incisional hernia/fluid leakage)	Risk of intra-abdominal organ damage – risk of bleeding
Short operative times	Difficult precise positioning of the intra-peritoneal segment – risk of catheter malfunctioning
	No security at end of procedure that catheter is in correct position.
Low cost procedure	Does not allow to perform associated procedures (i.e. adhesiolysis, omentopexy, partial omentectomy)

- A small incision is made above the entrance site, most commonly in the midline.
- An 18-gauge needle is placed into the peritoneal cavity, which is then filled with air or 500 mL of saline. Absence of resistance or pain during this manoeuvre suggests proper positioning.
- A guide wire (usually 0.035-in.) is then advanced into the abdomen, this step can be done under XR guidance, and the needle is removed.
- A dilator and a peel-a-way sheath are advanced over the guidewire into the abdominal cavity. The dilator and wire are then removed, and the peritoneal dialysis catheter is placed in the peritoneal cavity and advanced through the sheath with a stylet until the proximal cuff is in the preperitoneal sheath.

The peel-a-way sheath and the stylet are then removed, and the correct position of the catheter is confirmed with fluoroscopy (Table 5.2).

Peritoneoscopic Technique

First described in 1981 by Ash [44], it is a technique of PD catheter insertion under local anaesthesia. The peritoneoscopic PD catheter insertion, commonly performed by nephrologists in an outpatient setting with all the associated potential benefits [45, 46], requires a specialized equipment (needlescope - Y-TEC, Medigroup, Inc. North Aurora, IL).

There are still limited data on outcomes for these catheters. Main concerns are relatively high dysfunction rates [47] and risk of bowel perforation [48, 49]. The vast majority of data on outcomes are coming from retrospective studies outside the United States [50, 51]; very recently Yorg and coll. reported in a retrospective series the Mount Sinai experience [52].

Technical Aspects

Peritoneoscopic placement of peritoneal dialysis catheters, under local anaesthesia, requires a needle trocar, a Quill guide, a needlescope (needlescope - Y-TEC, Medigroup, Inc. North Aurora, IL) and a Cuff Implanter Tool (Medigroup Inc., Oswego, IL).

A guidewire and a peel-away sheath applying the Seldinger technique.

- Needle trocar and surrounding Quill guide or sheath insertion through abdominal wall.
- Insufflation of the peritoneal cavity with room air [44] or NO [52].
- Needlescope insertion through the Quill guide, identification of the pelvis.
- The scope is removed; the guide is dilated to 6 mm to allow the PD catheter insertion.
- Deep cuff positioning below the anterior rectus sheath using a Cuff Implanter Tool (Medigroup Inc., Oswego, IL).
- Guide removal (Table 5.3).

Open Surgical Technique

First described in 1972 by Brewer, the open surgical peritoneal dialysis catheter placement has been until recent years the most commonly used in the adult and pediatric population [53, 54]. Advantages and disadvantages of this technique are presented in the Table 5.4. Since there is direct visualization of the peritoneum prior to insertion, the risk of bowel injury and bleeding is extremely low [53]. However, its main limitation is catheter malfunctioning; the reported incidence in some series is up to a 38% [55]. Two major factors that may be involved in catheter dysfunction are inadequate placement of the catheter tip into the pelvis, which

Table 5.3 Pros and cons of peritoneoscopic insertion

Pros	Cons
Procedure under local anaesthesia	Not all types of catheters can be inserted
Small incision (low risk of incisional hernia/ fluid leakage)	Risk of intra-abdominal organ damage – risk of bleeding
Short operative times	Does not allow to perform associated procedures (i.e. adhesiolysis, omentopexy, partial omentectomy)
Visualization of the abdominal cavity and more accurate placement of the tip of the catheter than with blind percutaneous or open surgical	Need for specialized equipment and expertise

Table 5.4 Pros and cons of open insertion

Pros	Cons
All types of catheters can be inserted	Larger incision compared to other techniques and consequent higher risk of incisional hernia/fluid leakage
Low risk of intra-abdominal organ damage	Risk of catheter malfunctioning – catheter migration, one-way or total obstruction
Low risk of bleeding	Limited space to perform associated procedures (i.e. adhesiolysis, omentopexy, partial omentectomy)
	Costs – surgeon and OR time No security at end of procedure that catheter is in correct position.

OR operating room

allows the catheter to migrate and become entrapped within the omentum, and the presence of intra-abdominal adhesions, which interfere with correct catheter placement [56–59]. Using the mini-laparotomy, it is difficult to visualize the entire peritoneal cavity, and to perform adhesiolysis should it be required; therefore, potentially poorer outcomes are to be expected in patients who have had prior abdominal surgery [60].

Technical Aspects

Open surgical placement of peritoneal dialysis catheters, under local or general anaesthesia, is performed via a mini-laparotomy.

- The skin incision, in a patient placed in supine position, is either sub-umbilical midline or ideally para-median [61]. Stegmayr and coll. introduced the paramedian approach and purse string sutures around the peritoneum and the catheter to reduce the incidence of leak rate [61].
- The subcutaneous layer is then dissected to the sheath of the rectus muscle. The anterior rectus sheath is opened, and the muscle fibers are split (muscle-splitting technique). The posterior sheath is incised, and the abdominal cavity is opened after dissecting the peritoneum.
- Placing the patient in Trendelemburg position allows a confortable peritoneal catheter placement deep in the peritoneal cavity; this manoeuvre can be done with or without a stylet.
- Omentectomy is commonly performed in the pediatric population [54, 62] (for more details please refer to the section "Surgical Manoeuvres to Prevent Catheter Dysfunction")
- Some surgeons perform fixation of the intraperitoneal catheter portion to the bladder, the parietal peritoneum, uterus or pelvic sidewall in order to minimize catheter dislocation (for more details please refer to the section "Surgical Manoeuvres to Prevent Catheter Dysfunction").
- The deep cuff is positioned within the rectus sheath; some surgeons place reinforcing sutures in order to prevent leakage of the dialysate [61].
- The posterior and anterior rectus sheaths are closed with absorbable sutures taking care to prevent catheter obstruction.
- A subcutaneous tunnel is then created and the distal cuff left at 2–4 cm from the exit site [28].
- Filling the abdomen with sterile saline - with no consensus about the amount of fluid that should be given – in order to check good in- and outflow at the end of the procedure and for eventual leakage (Table 5.4).

Laparoscopic Technique

Since its first description in the early 1990s, laparoscopic insertion of PD catheters has been increasingly used, an it is now in the United States the most commonly technique used [36]; its safety and feasibility in both adults and children have been documented in case series, retrospective reviews and comparative studies [50, 63–98]. Advantages and disadvantages of this technique are presented in the Table 5.5. The laparoscopic peritoneal catheter insertion without any associated intervention is referred in the literature as "basic laparoscopic technique". There is a growing body of evidence that the greatest benefit of laparoscopy is the minimization of catheter dysfunction securing optimal catheter position under direct vision, facilitating adhesiolysis, rectus sheath tunneling, omentopexy or omentectomy.

The use of these surgical manoeuvres is referred to as "advanced laparoscopic techniques" (for more details please refer to the section "Surgical Manoeuvres to Prevent Catheter Dysfunction") [50, 91, 99].

Technical Aspects

The laparoscopic peritoneal dialysis placement can be performed under general or local anaesthesia.

Standard laparoscopes of thirty degrees zero degrees, 3, 5, 8 and 10 mm ports have all been used in the studies present in the literature. One, two and three port techniques have all been described. Graspers and scissors should be available as well as ultrasonic dissecting instruments since adhesiolysis is sometimes necessary.

Minilaparoscopic instruments have also been used with equal success [72, 100–103]. Most authors recommend the use of the smallest available non-cutting ports to allow the quickest healing of the peritoneum, thus facilitating early start of PD and low leak rate; studies comparing leak rates and the size of trocars are lacking.

1. Procedure under general anaesthesia:
    - The patient is placed in a supine position.
    - For every technique, it is important to first place the PD catheter on the abdomen of the patient and determine optimal position, insertion site and exit site. There are even tools to assist with this.
    - The access to the peritoneal cavity is accomplished either by open Hassan trocar or by Veress needle insertion. In a review, Crabtree noted that 43% of authors used a peri-umbilical site (subcostal or supraumbilical) [60]. From the available literature, it is clear that the access to the peritoneal cavity is at discretion of the operating surgeon; most authors are now less in favour to the midline access [61].
    - After induction of pneumoperitoneum (max pressure 12–14 mmHg), a diagnostic laparoscopy is performed. An additional 5–8 mm trocar is placed under direct vision at the site of the planned exit-site position of the peritoneal dialysis catheter. For the description of the rectus sheath tunnelling technique, please refer to the section on Surgical Manoeuvres to Prevent Catheter Dysfunction.
    - If adhesions are present, adhesiolysis is usually performed.
    - A peritoneal dialysis catheter is then placed into the pouch of Douglas, with or without a stylet.
    - The distal cuff of the peritoneal dialysis catheter remains outside of the peritoneal cavity and is positioned either in the pre-peritoneal space or between the rectus sheaths.
    - The para-umbilical trocar is removed, and the catheter is then directed to its exit-site location.
    - A subcutaneous tunnel is created similarly to others implantation techniques.
    - The catheter is tested, and the abdomen is desufflated.
    - The trocar is removed, and the rectus fascia closed. Skin closure (Table 5.5).

Table 5.5 Pros and cons: Laparoscopic PD catheter insertion under general anaesthesia

Pros	Cons
Small incision(s) (low risk of incisional hernia/fluid leakage)	Need for general anaesthetic (can also be done under LA, but GA more common)
Allows to perform associated procedures (i.e. adhesiolysis, omentopexy, partial omentectomy)	Expertise in laparoscopic surgery
Low risk of intra-abdominal organ damage/low risk of bleeding	Not all types of catheters can be inserted
Immediate use possible	Need for special equipment (problem for 3rd World countries)
Precise positioning (under direct vision) of intraperitoneal segment.	
Cost-effective*	

**Cost analysis* When accounting for a year of postoperative management and treatment, laparoscopic insertion can be less costly than open insertion in the hands of an experienced and dedicated surgeon. Despite higher initial costs, PD catheter insertion under laparoscopic visualization can have lower total costs due to fewer postoperative complications [109]

Procedure Under Local Anaesthesia

It is reported the original technique described by Crabtree of laparoscopic dialysis catheter implantation using a two-port technique [104]. The infiltration with local anaesthetic of all abdominal wall layers until the peritoneum, for complete pain control, helium insufflation is used to create pneumoperitoneum; Keshvari and coll. described the technique using nitrous oxide (NO_2) [64]. Few characteristics make helium ideal in this setting: it is painless, thereby allowing the laparoscopic procedure to be performed under local anaesthesia [104]; non-flammable, thereby safe when using electrosurgical devices [105, 106]; inert, thereby increasingly utilized in high-risk patients [107, 108]. Contrary to paralyzed patients under general anaesthesia, patients under local anesthesia benefit from lower gas insufflation pressure (between 8 and 10 mmHg) and rates (0.5–2.0 L/min.). The peritoneal catheter is inserted through a para-median port site while continuously monitoring the implant procedure with a laparoscope from a second port location. The catheter–stylet assembly is then inserted and placed deep in the pelvis. The rectus sheath tunnelling technique is applied. The deep Dacron cuff is withdrawn until disappears above the peritoneum in the anterior rectus sheath. The stylet is removed from the catheter, the pneumoperitoneum is allowed to deflate, and the laparoscope is removed. The catheter is tested with the patient in reverse Trendelemburg position; a standard 1-L bag of normal saline is observed for unimpeded inflow and drainage by gravity. A residual of 250–300 mL is left in the abdomen to reduce the likelihood of intraperitoneal structures sucking up against the catheter toward the end of the drainage process. At the conclusion of a successful irrigation, the entire system is flushed with 20 mL of heparin (100 U/mL) (Table 5.6).

Surgical Manoeuvres to Prevent Catheter Dysfunction

Adhesiolysis

Previous abdominal surgery and consequent peritoneal adhesion formation represent a unique challenge and a major factor in PD catheter dysfunction [110]. Although no studies specifically compared PD catheter placement and adhesiolysis to PD catheter placement alone, adhesiolysis is considered essential in optimising primary PD catheter function. In this context, the laparoscopic approach is particularly beneficial, allowing identification and lysis of the adhesions [65, 111]. Adhesiolysis can be performed using ultrasonic shears or regular laparoscopic scissors [60] and it has been employed in several large case series [63, 78, 80–82, 85, 111] and some authors described similar catheter function rates in patients with adhesions as those with a virgin abdomen [60, 112, 113].

Suture Fixation

Catheter tip migration away from the pelvis is a common cause for catheter failure as the intraperitoneal portion of the catheter functions best

Table 5.6 Pros and cons: Laparoscopic PD catheter insertion under local anaesthesia

Pros	Cons
No need for general anaesthesia	Not all types of catheters can be inserted
Small incision (low risk of incisional hernia/fluid leakage)	Need for special equipment
Allows to perform associated procedures (i.e. adhesiolysis, partial omentectomy)	Expertise in laparoscopic technique
Low risk of intra-abdominal organ damage/low risk of bleeding	Need for special equipment (problem for 3rd World countries)
Immediate use possible	
Precise positioning (under direct vision) of the intraperitoneal segment.	
Cost-effective[a]	

[a]***Cost analysis*** When accounting for a year of postoperative management and treatment, laparoscopic insertion can be less costly than open insertion in the hands of an experienced and dedicated surgeon. Despite higher initial costs, PD catheter insertion under laparoscopic visualization can have lower total costs due to fewer postoperative complications [109]

when in the pelvis [48, 49, 68]. Several authors reported suture fixation of the catheter tip to the bladder, uterus or pelvic sidewall in an attempt to prevent catheter tip migration in either open or laparoscopic approach [14, 59, 61, 62, 64]. Potential harms of suture fixation are not easy catheter removal and internal hernias or adhesions [93]. Other authors showed a relatively high dysfunction rate after suture fixation (12–14%), possibly due to the inability of the catheter to "float" into the largest area of PD fluid [14, 77, 93]. However, the lack of comparative studies on peritoneal catheter insertion with and without suture fixation leaves the decision on suture fixation to the operating surgeon, based on his personal experience.

Rectus Sheath Tunneling

Many authors have used rectus sheath tunneling, also described as extraperitoneal or preperitoneal tunneling, as a way to prevent catheter migration and decrease the incidence of fluid leak [78, 79, 82, 91, 94]. The technique, applied during laparoscopic insertion, involves visualizing the insertion device (sheath, blunt trocar or grasper) as it comes through the rectus muscle but before it enters the peritoneal cavity. Once the device is seen just above the posterior rectus sheath and peritoneum, it is tunnelled 4–6 cm toward the midline pelvis before actually penetrating and entering the peritoneal cavity. In addition, this technique has the advantage over suture fixation of not requiring extra trocars for suturing. Several studies using laparoscopic insertion and rectus sheath tunnel showed dysfunction rates between 4% and 8.6% and leak rates from 0% to 12.5% [78, 79, 82, 91, 94]. In a recent review article, Frost and Bagul recommend that rectus sheath tunneling and placement of the deep cuff in the rectus sheath are far more important than suture fixation in reducing catheter tip migration [99]. However, randomized trials comparing suture fixation to rectus sheath tunneling have not been performed.

Omentopexy and Omentectomy

The omentum is a well-known source of catheter dysfunction; omentectomy has been described in adults and children as a way to reduce this complication. With the open technique the omentum is pulled up through the incision and excised [54, 114–122]. McIntosh described an alternative technique, omentopexy, which consists in suturing the omentum to the abdominal wall [119]. Although omentectomy is feasible during laparoscopic PD catheter insertion [69, 111, 118, 120–122], it is more time consuming and has an increased risk of bleeding [65]; therefore, laparoscopic omentopexy seems to be favoured [67, 82, 94, 112, 113]. Omentopexy techniques can be accomplished with trans-abdominal suture passer or with intracorporeal suturing. An alternative technique described by Goh consists of omental folding in order to shorten it [122].

Critical Comparison of Different Implantation Techniques

Percutaneous – Peritoneoscopic Versus Surgical (Open or Laparoscopic)

Several single centre experiences compared percutaneous and open surgical peritoneal dialysis catheter insertion. Besides the general agreement that percutaneous insertion is particularly well suited for high-risk patients, who cannot tolerate general anaesthesia [42, 117, 118, 123, 124], comparative results yield to a different results. While older studies including a retrospective single center study by Nicholson and coll. found that catheter survival was significantly better after open surgical insertion compared to percutaneous insertion [115]. Gadallah and coll. in a prospective randomized study on percutaneous versus open placement of peritoneal dialysis catheters showed that the placement modality did not affect catheter survival; however, early mechanical complications, including technical failures, occurred more frequently in the percutaneous group [116]. More recent studies show that percutaneous placement of PD catheter offers an effective and safe alternative surgical technique in selected patients (such as no previous abdominal operation, BMI < 28 kg/m^2) [123–126]; a meta-analysis comparing open surgery/laparoscopic and percutaneous PD catheter insertion reports no difference in the 1-year catheter survival rate [127].

Open Versus Laparoscopic

A number of randomized prospective studies [88, 92, 95, 96, 128, 129] comparing open surgical versus laparoscopic peritoneal catheter insertion justified systematic reviews [130] and meta-analyses [131, 132].

The systematic review of randomized controlled trials conducted by Strippoli and coll. included any randomized controlled trial of different catheter types and catheter-related interventions used to prevent peritonitis or exit-site and tunnel infection in PD. The subgroup analysis on surgical approaches included three trials (248 patients in total) comparing laparoscopic versus open surgical catheter insertion, could not demonstrate any advantage of one technique over the other, with respect to the risk of peritonitis, catheter removal or replacement, technical failure and all-cause mortality [130].

Xie and coll. performed a meta-analysis of four randomized controlled trials and a systematic review of ten observational studies to compare laparoscopy with open placement of peritoneal dialysis catheter. The authors extracted data on the following reported outcomes: operation time, duration of hospital stay, incidence-rate of catheter-related complications (such as infection, dialysate leak, catheter migration, outflow obstruction, bleeding, blockage and hernia). According to this analysis open surgery needs a shorter operative time and simpler equipment requirement but has a similar effect to the laparoscopic technique. Therefore, the authors conclude that laparoscopic catheter placement has no superiority to open surgery; on the other hand, they state that further trials that focus on long-term outcomes are needed, taking into account the rapid development of the advanced laparoscopic technique, which may reduce further the complication rates [131].

Hagen and coll. performed a meta-analysis of three randomized controlled trials [85, 87, 88] and eight cohort studies [88, 90, 91, 93, 96, 101, 133, 134], comparing laparoscopic versus open surgical peritoneal catheter insertion. Contrarily to the study conducted by Xie and coll. [131], the authors did not include studies assessing different techniques (peritoneoscopic and percutaneous insertion) and studies including pediatric patients. The following outcome measures were included: incidence of peritonitis, exit-site/tunnel infection, leakage, catheter migration, catheter removal for complications, need for revision and catheter survival. The results of this meta-analysis reveal the potential benefits of laparoscopic PD-catheter insertion with better one-year catheter survival and less migration rates compared to the open surgical insertion [132].

The conclusion of both meta-analyses [131, 132] is the need of studies with larger numbers of patients and long-term follow up in order to be able to evaluate the true value of laparoscopy in PD-catheter insertion; a large randomized controlled trial is currently under way [129].

Limitations of Comparative Studies

Small numbers, single centre experiences and other confounding factors bias the studies comparing insertion techniques. The expertise of the operators, which may vary significantly, the exclusion of high-risk patients, such as those with history of prior abdominal surgery, in some insertion techniques, the different definitions of complications (for example some papers split up catheter migration and outflow obstruction as causes of catheter dysfunction), make comparative studies less accurate and difficult to interpret. Finally, the follow-up periods vary greatly, but generally tended to be short making it difficult to compare data on one technique versus another. For peritoneal access, the only strong recommendation that can be made is that all the techniques, percutaneous, open surgical, and laparoscopic insertion procedures, when performed by experienced/dedicated operators, are feasible and safe with acceptable outcomes.

Timing? When to Start PD After Catheter Insertion

The timing of commencement of dialysis after catheter insertion has not been studied in randomized controlled trials, although one is currently underway in Australia [135]. There is general consensus worldwide to observe a break in period of at least 2 weeks for both adult and children. [28, 135–140] (see table). Over the last decade, urgent-start PD has gained considerable interest in the United States. Urgent-start PD refers to an approach that involves initiation of PD therapy earlier than 2 weeks after PD catheter insertion. Treatment is performed with low fill volumes in the supine position using a cycler to avoid peri-catheter leak. Numerous clinical experiences with urgent-start PD have been published or discussed at scientific meetings [141–150].

With all the limitations of a single center including a small number of patients, Ghaffari recently described the feasibility and efficacy of an urgent-start peritoneal dialysis program [141].

British Renal Association (2009)	Whenever possible, that catheter insertion should be performed at least 2 weeks before starting peritoneal dialysis. Small dialysate volumes in the supine position can be used if dialysis is required earlier (2B).
European Dialysis and Transplant Association – European Renal Association (2005)	Whenever possible, the implantation should be at least 2 weeks before starting peritoneal dialysis. Small dialysate volumes in the supine position can be used if dialysis is required earlier (Evidence C)
Australian: Caring for Australasians with Renal Impairment (CARI) (2004)	When possible, peritoneal dialysis should not be commenced until at least 2 weeks after the insertion of the dialysis catheter (Suggestions are based on level III and IV studies)
International Society for Peritoneal Dialysis (ISPD)	When possible, peritoneal dialysis should not be commenced until at least 2 weeks after the insertion of the dialysis catheter
Kidney Disease Outcomes Quality Initiative (KDOQI)	No recommendations.
Canadian Society of Nephrology	No recommendations.

Surgical Complications and Management

(a) Hernia
(b) Hemorrhage
(c) Perforation
(d) Catheter-related (fluid leak, one-way or total obstruction, migration)
(e) Others (chyloperitoneum, genital edema, peritoneal-vaginal leak)

Hernia

Hernias represent one of the most frequent non-infectious complications of PD and will be extensively treated in a separate chapter [15].

Hemorrhage

Hemorrhage secondary to peritoneal catheter insertion can be classified as intraperitoneal and extraperitoneal.

Intraperitoneal bleeding (intraabdominal bleeding) may be secondary to trauma of omental or mesenteric vessels during the manipulation of the catheter tip into the pelvis, adhesiolysis or omentectomy. During a percutaneous insertion this is usually recognised as bloodstaining of the draining fluid. This complication may occur or be recognised only postoperatively and usually presents with bloody staining of the dialysate effluent. If the bleeding is minimal and the patient is hemodynamically stable, conservative management is indicated. Obviously, in case of severe bleeding and/or hemodynamic instability, patient should be taken back to theatres as emergency. During open and/or laparoscopic insertion it is easier to recognise and treat this complication.

Extraperitoneal bleeding may occur from the inferior epigastric vessels, subcutaneous vessels or skin edges. If the bleeding is difficult to control, the epigastric vessels can be tied off with ligature above and below the site of trauma. Bleeding from subcutaneous vessels and skin edges is in the vast majority of cases self-limiting or stops with conservative management; large hematomas may require surgical intervention in case of patient discomfort and potential source of infection [151].

Perforation

Intra-abdominal perforation is a described complication during peritoneal catheter insertion; it is more common during percutaneous insertion. The most commonly injured organs are bowel and bladder. Perforation of viscera by erosion of the peritoneal catheter is extremely rare. This complication is facilitated by episodes of peritonitis, an empty peritoneal cavity, the use of steroids, or the presence of vasculitis.

Lesions to the bladder occur more frequently in patients with chronic urinary outflow obstruction; some authors advocate the use of a urinary catheter to limit its occurrence. Urine in the peritoneal cavity may give rise to signs of peritonitis. A small laceration may close spontaneously draining the bladder with a urethral catheter. A large laceration may require a surgical repair followed by urethral catheterization.

The risk of bowel perforation is higher in patients with intra-abdominal adhesions from previous surgery or peritonitis. The most common mechanism of injury is advancement of the catheter against resistance into a bowel loop, fixed in the peritoneal cavity by adhesions; the pathogenetic mechanism previously described is characteristic of the percutaneous placement. During laparoscopic or open insertion, the insertion under direct vision makes this complication extremely rare.

After catheter insertion, perforation may present in a variety of ways. The patient without experiencing abdominal signs may pass large volumes of dialysate per rectum if the catheter is placed into the lumen of the bowel. Alternatively the run-out may be cloudy and contain mixed bacterial organisms with signs of peritonitis. Several courses of action are possible. In the absence of clinical signs and symptoms, the catheter may be left in free drainage for few days to allow an intra-peritoneal track to form, then it may be removed; few weeks are usually required before attempting a new catheter insertion.

In case of peritonitis or when conservative management fails, a diagnostic laparoscopy or laparotomy is mandatory.

Catheter-Related (Fluid Leak, One-Way or Total Obstruction)

Fluid Leak

Fluid leak is defined as the appearance of dialysate fluid through the wound(s) or he catheter exit site. It can be divided in early and late, depending upon its appearance soon after the insertion or at later stage. The wide variety of its incidence (from 0% to 27%) present in the literature mostly depends on the technique of implantation (percutaneous vs peritoneoscopic vs open vs laparoscopic) and the definition of leak (early vs late) [85, 86, 89, 100, 152–154]. The vast majority are represented by early leaks. The pathogenesis is due to a defect in the peritoneal closure around the catheter or other peritoneal defects created during insertion [154]. Preventive measures reported in the literature are the observation of a break-in period of about 2 weeks [89, 91]; in this period the wound can heal properly and ingrowth of fibrous tissue can anchor the catheter. If the start cannot be delayed, it would be reasonable reducing the dialysate volume (500–1000 mL in adults) for the initial period. There is also evidence that the laparoscopic insertion and the application of advanced techniques such as rectus sheath tunneling could further reduce the incidence of this complication [50].

One-Way or Total Obstruction

Catheter obstruction is one of the most common complications of peritoneal catheters; it usually occurs in the early postoperative phase and presents in the form of one-way (outflow) or total (inflow/outflow) obstruction. Its incidence varies widely depending on the catheter type and the technique applied. One-way obstruction presents when peritoneal fluid runs into the peritoneal cavity but only drains slowly or does not drain at all; total obstruction presents with inability to flush the catheter. The most common cause of obstruction and consequently catheter malfunctioning is catheter tip migration away from the pelvis [57, 58]. As described before, preventive surgical techniques have been applied in order to reduce its incidence, such as suture fixation of the catheter tip [58, 88, 118] and rectus sheath tunneling. The latter seems to yield the most promising results [99]. Other potential causes of obstruction are omental wrapping, presence of adhesions, full rectum or bladder, obstruction of the lumen with clots or fibrin [62].

The management of catheter obstruction depends on the cause. History and physical examination are important to identify the nature of the problem (sudden vs gradual) and to rule out constipation. A plain abdominal X-ray will give further information regarding constipation and will show the position of the catheter tip. If negative, further studies such as catheterography [155] or CT peritoneography [156, 157] followed by diagnostic laparoscopy [158] are indicated.

Non-operative treatments of malfunctioning PD catheters include laxatives or enemas, catheter flushing, intraluminal heparin or fibrinolytic agents [159–161]. Several procedures under fluoroscopic guidance have been described to reposition displaced catheters [162–165]. The manipulation of catheters with intraluminal instruments may predispose to visceral damage, bacterial contamination [166] and it is ineffective in case of adhesions or omental wrapping. Patients with malfunctioning peritoneal dialysis catheters not responding to non-operative treatments require operative management. The laparoscopic approach is particularly beneficial in this context, allowing catheter repositioning [167], adhesiolysis [67], omentectomy or omentopexy [89, 120] or catheter replacement when the obstruction can not be resolved [168].

Others (Chyloperitoneum, Genital Edema, Peritoneal-Vaginal Leak)

Chyloperitoneum

Chyloperitoneum is a rare but well-described complication in patients on peritoneal dialysis [169]. One case series reported an incidence of 0.5% [170]. It has been described after laparoscopic [169–171] and percutaneous [172] PD catheter placement. Its pathogenesis is unclear but has been hypothesized that could be secondary to injury of fine lymphatic vessels. The complication is usually recognised postoperatively when the dialysate has a milky white, turbid appearance and contains triglyceride levels that exceed those in the plasma [173]. Most cases resolve spontaneously within weeks but may require temporary cessation of PD. In persistent chyloperitoneum, conservative management consists of low fat diet to reduce the turbidity of the triglyceride-rich lymphatic flow; supplements with medium-chain triglycerides, absorbed directly into the portal system instead of intestinal lymphatics. Some authors achieved good results with Orlistat, a reversible inhibitor of pancreatic and gastric lipases, and octreotide, a somatostatin analogue, but the overall clinical experience with these agents is limited for this indication [174, 175]. Surgery may be indicated and some authors have advocated a laparoscopic approach [176].

Genital Edema

Genital, scrotal or labial, edema is typically secondary to two main causes: a patent processus vaginalis or a subcutaneous tissue leak of dialysate.

The most common pathogenetic cause is a patent processus vaginalis, which usually allows the flow of dialysate in the genital area and it is too small for the formation of a true hernia.

Patients with subcutaneous leaks will often have signs of leak in the subcutaneous tissue of the lower abdomen with evidence of these changes continuing into the genital area, such as palpable thickness of the tissue or visible peau d'orange appearance of the surrounding skin.

To differentiate between these presentations and to confirm the diagnosis, a CT peritoneogram or nuclear medicine scan can be useful. In CT peritoneography, 150 mL of contrast can be added to the 2 L dialysate bag and infused into the patient. The patient is asked to remain active for 30–60 min and then undergo a CT scan of the abdomen and processus vaginalis. Similarly, Tc-99m can be infused with the dialysate and after a similar period the patient undergoes to peritoneal scintigraphy.

In patients diagnosed with a patent processus vaginalis, surgical correction is usually required to resolve the genital edema, if a trial of night exchanges with dry days fails. [177]

Peritoneal-Vaginal Leak

This complication develops when the fallopian tubes act as conduits for antegrade passage of dialysate in the uterine cavity. The leak can be stopped by bilateral tubal ligation [178]. If the women wish to maintain fertility and transplantation is planned, temporary conversion to hemodialysis may be considered.

Bibliography

1. AV Fistula First Breakthrough Coalition. National Vascular Access Improvement Initiative (NVAII). Available at: http://www.fistulafirst.org/ Accessed 18 Jan 2009.
2. National Vascular Access Improvement Project. CMS launches "Fistula First" initiative to improve care and quality of life for hemodialysis patients. Press release April 14, 2004. http://www.cms.hhs.gov/aaps/media/press/release.asp?counter=1007.
3. van Biesen W, Veys N. Norbert Lameire and Raymond Vanholder Why less success of the peritoneal dialysis programmes in Europe? Nephrol Dial Transplant. 2008;23(5):1478–81.
4. Tenckhoff J, Schechter H. A bacteriologically safe peritoneal access device. Trans Am Soc Artif Intern Organs. 1968;14:181–7.
5. Ash SR, Nichols WK. Placement, repair and removal of chronic peritoneal catheters. In: Gokal R, Nolph KD, editors. Textbook of peritoneal dialysis. Boston: Kluwer Academic; 1994.
6. Diaz-Buxo JA, Geissinger WT. Single versus double cuff Tenckhoff catheters. Perit Dial Bull. 1984;4:100.
7. Oreopoulos DG, Izatt S, Zellerman G, et al. A prospective study of the effectiveness of three permanent peritoneal catheters. Proc Clin Dial Transplant Forum. 1976;6:96–100.
8. Twardowski ZJ, Nichols WK, Khanna R, Nolph KD. Swan-neck Missouri peritoneal dialysis catheters: design, insertion and break-in (video). Columbia: University of Missouri, Academic Support Center; 1993.
9. Twardowski ZJ, Prowant BF, Nichols WK, et al. Six-year experience with swan-neck catheter. Peril Dial Int. 1992;12:384–9.
10. Crabtree JH, Siddiqi RA, Chung JJ, Greenwald LT. Long-term experience with polyurethane, pail handle, coiled tip peritoneal dialysis catheters. ASAIO J. 1998;44(4):309–13.
11. Twardowski ZJ, Prowant BF, Pickett B, et al. Four-year experience with swan-neck pre-sternal peritoneal dialysis catheter. Am J Kidney Dis. 1996;27:99–105.
12. Twardowski ZJ. Presternal peritoneal catheter. Adv Ren Replace Ther. 2002;9(2):125–32.
13. Moncrief JW, Popovich RP, Broadrick LJ. New peritoneal access technique for CAPD (Abstract). Perit Dial Int. 1991;11(Suppl 1):A180.
14. Moncrief JW, Popovich RP, Broadrick LJ, He ZZ, Simmons EE, Tate RA. The Moncrief-Popovich catheter: a new peritoneal access technique for patients on peritoneal dialysis. ASAIO J. 1993;39(1):62–5.
15. Ash SR. Experience with a new catheter design. Twenty-first conference on dialysis proceedings. New Orleans. LA, 19–21 Feb 2001, p. 303–5.
16. Shinaberger JH, Shear L, Barry KG. Peritoneal extracorporeal recirculation dialysis: a technique for improving efficiency of peritoneal dialysis. Invest Urol. 1965;2:555–65.
17. Lange K, Treser G, Mangalat J. Automatic continuous high flow rate peritoneal dialysis. Arch Klin Med. 1968;214:201–6.
18. Raja RM, Kramer MS, Rosenbaum JL. Recirculating peritoneal dialysis with Sorbent Redy cartridge. Nephron. 1976;16:134–42.
19. Kabitz C, Stephen RL, Jacobsen SC, et al. Reciprocating peritoneal dialysis. Dial Transplant. 1978;7:211–4.
20. Kraus MA, Shasha SM, Nemas M, et al. Ultrafiltration peritoneal dialysis and recirculating peritoneal dialysis with a portable kidney. Dial Transplant. 1983;12:385–8.
21. Mineshima M, Watanuki M, Yamagata K, et al. Development of continuous recirculating peritoneal dialysis using a double lumen catheter. ASAIO J. 1992;38:M377–81.

22. Diaz–Buxo JA, Folden TI. Optimization of peritoneal dialysis: a bioengineering approach. Semin Dial. 1999;12:S97–100.
23. Passlick–Deetjen J, Quellhorst E. Continuous flow peritoneal dialysis (CFPD): a glimpse into the future. Nephrol Dial Transplant. 2001;16:2296–9.
24. Diaz–Buxo JA. Streaming, mixing, and recirculation: role of the peritoneal access in continuous flow peritoneal dialysis (clinical considerations). Adv Perit Dial. 2002;18:87–90.
25. Ash SR, Janle EM. Continuous flow-through peritoneal dialysis: comparison of efficiency to IPD, TPD and CAPD in an animal model. Perit Dial Int. 1997;17:365–72.
26. Ronco C, Gloukhoff A, Dell'Aquila R, Levin NW. Catheter design for continuous flow peritoneal dialysis. Blood Purif. 2002;20:40–4.
27. Lewis MA, Smith T, Postlethwaite RJ, Webb NJ. A comparison of double-cuffed with single-cuffed Tenckhoff catheters in the prevention of infection in pediatric patients. Adv Perit Dial. 1997;13:274–6.
28. Gokal R, Alexander S, Ash S, Chen TW, Danielson A, Holmes C, Joffe P, Moncrief J, Nichols K, Piraino B, Prowant B, Slingeneyer A, Stegmayr B, Twardowski Z, Vas S. Peritoneal catheters and exit-site practices toward optimum peritoneal access: 1998 update. (Official report from the International Society for Peritoneal Dialysis). Perit Dial Int. 1998;18:11–33.
29. Eklund B, Honkanen E, Kyllönen L, Salmela K, Kala AR. Peritoneal dialysis access: prospective randomized comparison of single-cuff and double-cuff straight Tenckhoff catheters. Nephrol Dial Transplant. 1997;12(12):2664–6.
30. Swartz R, Messana J, Rocher L, Reynolds J, Starmann B, et al. The curled catheter: dependable device for percutaneous peritoneal access. Perit Dial Int. 1990;10:231–5.
31. Nielsen PK, Hemmingsen C, Friis SU, Ladefoged J, Olgaard K. Comparison of straight and curled Tenckhoff peritoneal dialysis catheters implanted by percutaneous technique: a prospective randomized study. Perit Dial Int. 1995;15:18–21.
32. Johnson DW, Wong J, Wiggins KJ, Kirwan R, Griffin A, et al. A randomized controlled trial of coiled versus straight swan-neck Tenckhoff catheters in peritoneal dialysis patients. Am J Kidney Dis. 2006;48:812–21.
33. Xie J, Kiryluk K, Ren H, et al. Coiled versus straight peritoneal dialysis catheters: a randomized controlled trial and meta-analysis. Am J Kidney Dis. 2011;58(6):946–55.
34. Hagen SM, Lafranca JA, IJzermans JN, Dor FJ. A systematic review and meta-analysis of the influence of peritoneal dialysis catheter type on complication rate and catheter survival. Kidney Int. 2014;85(4):920–32.
35. Hagen SM, Lafranca JA, Steyerberg EW, IJzermans JN, Dor FJ. Laparoscopic versus open peritoneal dialysis catheter insertion: a meta-analysis. PLoS ONE. 2013;8(2):e56351.
36. Distribution of 2007–2014 CMS Part B Claims for CPT 49324 (Laparoscopy) and all other methods (Open and percutaneous needle-guidewire) – physician/supplier procedure summary master file 2007–2014 Medicare, Baltimore, MD – Centers for Medicare and Medicaid Services, Department of Health and Human Services.
37. Zappacosta AR, Perras ST, Closkey GM. Seldinger technique for Tenckhoff catheter placement. ASAIO Trans. 1991;37:13–5.
38. Napoli M, Russo F, Mastrangelo F. Placement of peritoneal dialysis catheter by percutaneous method with the Veress needle. Adv Perit Dial. 2000;16:165–9.
39. Banli O, Altun H, Oztemel A. Early start of CAPD with the Seldinger technique. Perit Dial Int. 2005;25:556–9.
40. Allon M, Soucie JM, Macon EJ. Complications with permanent peritoneal dialysis catheters: experience with 154 percutaneously placed catheters. Nephron. 1998;48:8–11.
41. 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.
42. Aksu N, Yavascan O, Anil M, Kara OD, Erdogan H, Bal A. A ten-year single centre experience in children on chronic peritoneal dialysis – significance of percutaneous placement of peritoneal dialysis catheters. Nephrol Dial Transplant. 2007;22:2045–51.
43. Varughese S, Sundaram M, Basu G, Tamilarasi V, John GT. Percutaneous continuous ambulatory peritoneal dialysis (CAPD) catheter insertion – a preferred option for developing countries. Trop Doct. 2010;40:104–5.
44. Ash S, Wolf GC, Bloch R. Placement of the Tenckhoff peritoneal dialysis catheter under peritoneoscopic visualization. Dial Transplant. 1981;10:383–5.
45. Goh BL, Ganeshadeva YM, Chew SE, Dalimi MS. Does peritoneal dialysis catheter insertion by interventional nephrologists enhance peritoneal dialysis penetration? Semin Dial. 2008;21:561–6.
46. Li PK, Chow KM. Importance of peritoneal dialysis catheter insertion by nephrologists: practice makes perfect. Nephrol Dial Transplant. 2009;24:3274–6.
47. Maffei S, Bonello F, Stramignoni E, Forneris G, Iadarola GM, Borca M, Quarello F. Two years of experience and 119 peritoneal dialysis catheters placed with peritoneoscopy control and Y-TEC system. Minerva Urol Nefrol. 1992;44:63–7.
48. Nahman Jr NS, Middendorf DF, Bay WH, McElligott R, Powell S, Anderson J. Modification of the percutaneous approach to peritoneal dialysis catheter placement under peritoneoscopic visualization: clinical results in 78 patients. J Am Soc Nephrol. 1992;3:103–7.

49. Asif A, Byers P, Vieira CF, Merrill D, Gadalean F, Bourgoignie JJ, Leclercq B, Roth D, Gadallah MF. Peritoneoscopic placement of peritoneal dialysis catheter and bowel perforation: experience of an interventional nephrology program. Am J Kidney Dis. 2003;42:1270–4.
50. Haggerty S, Roth S, Walsh D, Stefanidis D, Price R, Fanelli RD, Penner T, Richardson W, SAGES Guidelines Committee. Guidelines for laparoscopic peritoneal dialysis access surgery. Surg Endosc. 2014;28(11):3016–45.
51. Kelly J, McNamara K, May S. Peritoneoscopic peritoneal dialysis catheter insertion. Nephrology (Carlton). 2003;8:315–7.
52. Al Azzi Y, Zeldis E, Nadkarni GN, Schanzer H, Uribarri J. Outcomes of dialysis catheters placed by the Y-TEC peritoneoscopic technique: a single-center surgical experience. Clin Kidney J. 2016;9(1):158–61.
53. Brewer TE, Caldwell FT, Patterson RM, Flanigan WJ. Indwelling peritoneal (Tenckhoff) dialysis catheter. Experience with 24 patients. JAMA. 1972;219:1011–5.
54. Washburn KK, Currier H, Salter KJ, Brandt ML. Surgical technique for peritoneal dialysis catheter placement in the pediatric patient: a North American survey. Adv Perit Dial. 2004;20:218–21.
55. Brandt ML, Brewer ED. Peritoneal catheter placement in children. In: Nissenson A, Fine RN, editors. Handbook of dialysis therapy. Philadelphia: Saunders (Elsevier Inc.); 2008. p. 1295–301.
56. Rubin J, Adair CM, Raju S, Bower JD. The Tenckhoff catheter for peritoneal dialysis – an appraisal. Nephron. 1982;32:370–4.
57. Cronen PW, Moss JP, Simpson T, Rao M, Cowles L. Tenckhoff catheter placement: surgical aspects. Am Surg. 1985;51:627–9.
58. Bullmaster JR, Miller SF, Finley Jr RK, Jones LM. Surgical aspects of the Tenckhoff peritoneal dialysis catheter. A 7 year experience. Am J Surg. 1985;149:339–42.
59. Olcott C, Feldman CA, Coplon NS, Oppenheimer ML, Mehigan JT. Continuous ambulatory peritoneal dialysis. Technique of catheter insertion and management of associated surgical complications. Am J Surg. 1983;146:98–102.
60. Crabtree JH. The use of the laparoscope for dialysis catheter implantation: valuable carry-on or excess baggage? Perit Dial Int. 2009;29:394–406.
61. Stegmayr BG. Lateral catheter insertion together with three purse-string sutures reduces the risk for leakage during peritoneal dialysis. Artif Organs. 1994;18:309–13.
62. Swartz RD. Chronic peritoneal dialysis: mechanical and infectious complications. Nephron. 1985;40:29–37.
63. Maio R, Figueiredo N, Costa P. Laparoscopic placement of Tenckhoff catheters for peritoneal dialysis: a safe, effective, and reproducible procedure. Perit Dial Int. 2008;28:170–3.
64. Keshvari A, Najafi I, Jafari-Javid M, Yunesian M, Chaman R, Taromlou MN. Laparoscopic peritoneal dialysis catheter implantation using a Tenckhoff trocar under local anesthesia with nitrous oxide gas insufflation. Am J Surg. 2009;197:8–13.
65. Mattioli G, Castagnetti M, Verrina E, Trivelli A, Torre M, Jasonni V, Perfumo F. Laparoscopic-assisted peritoneal dialysis catheter implantation in pediatric patients. Urology. 2007;69:1185–9.
66. Milliken I, Fitzpatrick M, Subramaniam R. Single-port laparoscopic insertion of peritoneal dialysis catheters in children. J Pediatr Urol. 2006;2:308–11.
67. Kurihara S, Akiba T, Takeuchi M, Nakajima K, Inoue H, Yoneshima H. Laparoscopic mesenterioadhesiotomy and Tenckhoff catheter placement in patients with predisposing abdominal surgery. Artif Organs. 1995;19:1248–50.
68. Harissis HV, Katsios CS, Koliousi EL, Ikonomou MG, Siamopoulos KC, Fatouros M, Kappas AM. A new simplified one port laparoscopic technique of peritoneal dialysis catheter placement with intra-abdominal fixation. Am J Surg. 2006;192:125–9.
69. Wang JY, Hsieh JS, Chen FM, Chuan CH, Chan HM, Huang TJ. Secure placement of continuous ambulatory peritoneal dialysis catheters under laparoscopic assistance. Am Surg. 1999;65:247–9.
70. Watson DI, Paterson D, Bannister K. Secure placement of peritoneal dialysis catheters using a laparoscopic technique. Surg Laparosc Endosc. 1996;6:35–7.
71. Ogunc G. Videolaparoscopy with omentopexy: a new technique to allow placement of a catheter for continuous ambulatory peritoneal dialysis. Surg Today. 2001;31:942–4.
72. Haggerty SP, Zeni TM, Carder M, Frantzides CT. Laparoscopic peritoneal dialysis catheter insertion using a Quinton percutaneous insertion kit. JSLS. 2007;11:208–14.
73. Comert M, Borazan A, Kulah E, Ucan BH. A new laparoscopic technique for the placement of a permanent peritoneal dialysis catheter: the preperitoneal tunneling method. Surg Endosc. 2005;19:245–8.
74. Barone GW, Lightfoot ML, Ketel BL. Technique for laparoscopy-assisted complicated peritoneal dialysis catheter placement. J Laparoendosc Adv Surg Tech A. 2002;12:53–5.
75. Al-Dohayan A. Laparoscopic placement of peritoneal dialysis catheter (same day dialysis). JSLS. 1999;3:327–9.
76. Al-Hashemy AM, Seleem MI, Al-Ahmary AM, Bin-Mahfooz AA. A two-port laparoscopic placement of peritoneal dialysis catheter: a preliminary report. Saudi J Kidney Dis Transpl. 2004;15:144–8.
77. Brownlee J, Elkhairi S. Laparoscopic assisted placement of peritoneal dialysis catheter: a preliminary experience. Clin Nephrol. 1997;47:122–4.
78. Caliskan K, Nursal TZ, Tarim AM, Noyan T, Moray G, Haberal M. The adequacy of laparoscopy for continuous ambulatory peritoneal dialysis procedures. Transplant Proc. 2007;39:1359–61.
79. Leung LC, Yiu MK, Man CW, Chan WH, Lee KW, Lau KW. Laparoscopic management of Tenchkoff

catheters in continuous ambulatory peritoneal dialysis. A one port technique. Surg Endosc. 1998;12:891–3.
80. Manouras AJ, Kekis PB, Stamou KM, Konstadoulakis MM, Apostolidis NS. Laparoscopic placement of Oreopoulos-Zellerman catheters in CAPD patients. Perit Dial Int. 2004;24:252–5.
81. Nijhuis PH, Smulders JF, Jakimowicz JJ. Laparoscopic introduction of a continuous ambulatory peritoneal dialysis (capd) catheter by a two-puncture technique. Surg Endosc. 1996;10:676–9.
82. Yan X, Zhu W, Jiang CM, Huang HF, Zhang M, Guo HQ. Clinical application of one-port laparoscopic placement of peritoneal dialysis catheters. Scand J Urol Nephrol. 2010;44:341–4.
83. Ko J, Ra W, Bae T, Lee T, Kim HH, Han HS. Two-port laparoscopic placement of a peritoneal dialysis catheter with abdominal wall fixation. Surg Today. 2009;39:356–8.
84. Bar-Zohar D, Sagie B, Lubezky N, Blum M, Klausner J, Abu-Abeid S. Laparoscopic implantation of the Tenckhoff catheter for the treatment of end-stage renal failure and congestive heart failure: experience with the pelvic fixation technique. Isr Med Assoc J. 2006;8:174–8.
85. Schmidt SC, Pohle C, Langrehr JM, Schumacher G, Jacob D, Neuhaus P. Laparoscopic-assisted placement of peritoneal dialysis catheters: implantation technique and results. J Laparoendosc Adv Surg Tech A. 2007;17:596–9.
86. Crabtree JH, Burchette RJ. Effective use of laparoscopy for long-term peritoneal dialysis access. Am J Surg. 2009;198:135–41.
87. Poole GH, Tervit P. Laparoscopic Tenckhoff catheter insertion: a prospective study of a new technique. Aust N Z J Surg. 2000;70:371–3.
88. Soontrapornchai P, Simapatanapong T. Comparison of open and laparoscopic secure placement of peritoneal dialysis catheters. Surg Endosc. 2005;19:137–9.
89. Attaluri V, Lebeis C, Brethauer S, Rosenblatt S. Advanced laparoscopic techniques significantly improve function of peritoneal dialysis catheters. J Am Coll Surg. 2010;211(6):699–704.
90. Ogunc G, Tuncer M, Ogunc D, Yardimsever M, Ersoy F. Laparoscopic omental fixation technique versus open surgical placement of peritoneal dialysis catheters. Surg Endosc. 2003;17:1749–55.
91. Crabtree JH, Fishman A. A laparoscopic method for optimal peritoneal dialysis access. Am Surg. 2005;71(2):135–43.
92. Wright MJ, Bel'eed K, Johnson BF, Eadington DW, Sellars L, Farr MJ. Randomized prospective comparison of laparoscopic and open peritoneal dialysis catheter insertion. Perit Dial Int. 1999;19:372–5.
93. Draganic B, James A, Booth M, Gani JS. Comparative experience of a simple technique for laparoscopic chronic ambulatory peritoneal dialysis catheter placement. Aust N Z J Surg. 1998;68:735–9.
94. Blessing Jr WD, Ross JM, Kennedy CI, Richardson WS. Laparoscopic-assisted peritoneal dialysis catheter placement, an improvement on the single trocar technique. Am Surg. 2005;71:1042–6.
95. Jwo SC, Chen KS, Lee CC, Chen HY. Prospective randomized study for comparison of open surgery with laparoscopic-assisted placement of Tenckhoff peritoneal dialysis catheter – a single center experience and literature review. J Surg Res. 2010;159:489–96.
96. Gajjar AH, Rhoden DH, Kathuria P, Kaul R, Udupa AD, Jennings WC. Peritoneal dialysis catheters: laparoscopic versus traditional placement techniques and outcomes. Am J Surg. 2007;194:872–5; discussion 875–876.
97. Daschner M, Gfrorer S, Zachariou Z, Mehls O, Schaefer F. Laparoscopic Tenckhoff catheter implantation in children. Perit Dial Int. 2002;22:22–6.
98. Jwo SC, Chen KS, Lin YY. Video-assisted laparoscopic procedures in peritoneal dialysis. Surg Endosc. 2003;17:1666–70.
99. Frost JH, Bagul A. A brief recap of tips and surgical manoeuvres to enhance optimal outcome of surgically placed peritoneal dialysis catheters. Int J Nephrol. 2012;251584
100. Ogunc G. Minilaparoscopic extraperitoneal tunneling with omentopexy: a new technique for CAPD catheter placement. Perit Dial Int. 2005;25:551–5.
101. Batey CA, Crane JJ, Jenkins MA, Johnston TD, Munch LC. Minilaparoscopy-assisted placement of Tenckhoff catheters: an improved technique to facilitate peritoneal dialysis. J Endourol. 2002;16:681–4.
102. Varela JE, Elli EF, Vanuno D, Horgan S. Minilaparoscopic placement of a peritoneal dialysis catheter. Surg Endosc. 2003;7:2025–7.
103. Yun EJ, Meng MV, Brennan TV, McAninch JW, Santucci RA, Rogers SJ. Novel microlaparoscopic technique for peritoneal dialysis catheter placement. Urology. 2003;61:1026–8.
104. Crabtree JH, Fishman A. A laparoscopic approach under local anesthesia for peritoneal dialysis access. Perit Dial Int. 2000;20:757–65.
105. Bhoyrul S, Mori T, Way LW. Radially expanding dilatation. A superior method of laparoscopic trocar access. Surg Endosc. 1996;10:775–8.
106. Fleming RYD, Dougherty TB, Feig BW. The safety of helium for abdominal insufflation. Surg Endosc. 1997;11:230–4.
107. McMahon AJ, Baxter JN, Murray W, Imrie CW, Kenny G, O'Dwyer PJ. Helium pneumoperitoneum for laparoscopic cholecystectomy: ventilatory and blood gas changes. Br J Surg. 1994;81:1033–6.
108. Neuberger TJ, Andrus CH, Wittgen CM, Wade TP, Kaminski DL. Prospective comparison of helium versus carbon dioxide pneumoperitoneum. Gastrointest Endosc. 1996;43:38–41.
109. Davis WT, Dageforde LA, Moore DE. Laparoscopic versus open peritoneal dialysis catheter insertion cost analysis. J Surg Res. 2014;187(1):182–8.
110. Chen S-Y, Chen T-W, Lin S-H, Chen C-J, Yu J-C, Lin C-H. Does previous abdominal surgery increase postoperative complication rates in continuous

ambulatory peritoneal dialysis? Perit Dial Int. 2007;27:557–9.

111. Wang JY, Chen FM, Huang TJ, Hou MF, Huang CJ, Chan HM, Cheng KI, Cheng HC, Hsieh JS. Laparoscopic assisted placement of peritoneal dialysis catheters for selected patients with previous abdominal operation. J Invest Surg. 2005;18:59–62.
112. Lu CT, Watson DI, Elias TJ, Faull RJ, Clarkson AR, Bannister KM. Laparoscopic placement of peritoneal dialysis catheters: 7 years experience. ANZ J Surg. 2003;73:109–11.
113. Crabtree JH, Burchette RJ. Effect of prior abdominal surgery, peritonitis, and adhesions on catheter function and long-term outcome on peritoneal dialysis. Am Surg. 2009;75:140–7.
114. Henderson S, Brown E, Levy J. Safety and efficacy of percutaneous insertion of peritoneal dialysis catheters under sedation and local anaesthetic. Nephrol Dial Transplant. 2009 Nov;24(11):3499–504.
115. Nicholson ML, Donnelly PK, Burton PR, Veitch PS, Walls J. Factors influencing peritoneal catheter survival in continuous ambulatory peritoneal dialysis. Ann R Coll Surg Engl. 1990;72:368–72.
116. Gadallah MF, Pervez A, el-Shahawy MA, Sorrells D, Zibari G, McDonald J, Work J. Peritoneoscopic versus surgical placement of peritoneal dialysis catheters: a prospective randomized study on outcome. Am J Kidney Dis. 1999;33(1):118–22.
117. Keshvari A, Fazeli MS, Meysamie A, Seifi S, Taromloo MK. The effects of previous abdominal operations and intraperitoneal adhesions on the outcome of peritoneal dialysis catheters. Perit Dial Int. 2008;30:41–5.
118. Numanoglu A, Rasche L, Roth MA, McCulloch MI, Rode H. Laparoscopic insertion with tip suturing, omentectomy, and ovariopexy improves lifespan of peritoneal dialysis catheters in children. J Laparoendosc Adv Surg Tech A. 2008;18:302–5.
119. McIntosh G, Hurst PA, Young AE. The 'omental hitch' for the prevention of obstruction to peritoneal dialysis catheters. Br J Surg. 1985;72:880.
120. Crabtree JH, Fishman A. Laparoscopic omentectomy for peritoneal dialysis catheter flow obstruction: a case report and review of the literature. Surg Laparosc Endosc Percutan Tech. 1999;9: 228–33.
121. Crabtree JH, Fishman A. Selective performance of prophylactic omentopexy during laparoscopic implantation of peritoneal dialysis catheters. Surg Laparosc Endosc Percutan Tech. 2003;13:180–4.
122. Goh YH. Omental folding: a novel laparoscopic technique for salvaging peritoneal dialysis catheters. Perit Dial Int. 2008;28:626–31.
123. Medani S, Shantier M, Hussein W, Wall C, Mellotte G. A comparative analysis of percutaneous and open surgical techniques for peritoneal catheter placement. Perit Dial Int. 2012;32(6):628–35.
124. Ozener C, Bihorac A, Akoglu E. Technical survival of CAPD catheters: comparison between percutaneous and conventional surgical placement techniques. Nephrol Dial Transplant. 2001;16:1893–9.
125. Nicholas J, Thomas M, Adkins R, Sandhu K, Smith S, Odum J, Dasgupta I. Percutaneous and surgical peritoneal dialysis catheter placements have comparable outcomes in the modern era. Perit Dial Int. 2014;34:552–6.
126. Medani S, Hussein W, Shantier M, Flynn R, Wall C, Mellotte G. Comparison of percutaneous and open surgical techniques for first-time peritoneal dialysis catheter placement in the unbreached peritoneum. Perit Dial Int. 2015;35(5):576–85.
127. Tullavardhana T, Akranurakkul P, Ungkitphaiboon W, Songtish D. Surgical versus percutaneous techniques for peritoneal dialysis catheter placement: a meta-analysis of the outcomes. Ann Med Surg (Lond). 2016;10:11–8.
128. Lo WK, Lui SL, Li FK, Choy BY, Lam MF, et al. A prospective randomized study on three different peritoneal dialysis catheters. Perit Dial Int. 2003;23(Suppl 2):S127–31.
129. Hagen SM, van Alphen AM, Ijzermans JN, Dor FJ. Laparoscopic versus open peritoneal dialysis catheter insertion, the LOCI-trial: a study protocol. BMC Surg. 2011;(11):35.
130. Strippoli GFM, Tong A, Johnson D, et al. Catheter-related interventions to prevent peritonitis in peritoneal dialysis: a systematic review of randomized, controlled trials. J Am Soc Nephrol. 2004;15:2735–46.
131. Xie H, Zhang W, Cheng J, He Q. Laparoscopic versus open catheter placement in peritoneal dialysis patients: a systematic review and meta-analysis. BMC Nephrol. 2012;13(1):69.
132. Hagen SM, Lafranca JA, Steyerberg EW, IJzermans JN, Dor FJ. Laparoscopic versus open peritoneal dialysis catheter insertion: a meta-analysis. PLoS One. 2013;8(2):e56351.
133. Lund L, Jonler M. Peritoneal dialysis catheter placement: is laparoscopy an option? Int Urol Nephrol. 2007;39:625–8.
134. Li JR, Chen WM, Yang CK, Shu KH, Ou YC, et al. A novel method of laparoscopy-assisted peritoneal dialysis catheter placement. Surg Laparosc Endosc Percutan Tech. 2011;21:106–10.
135. The CARI Guidelines. Evidence for peritonitis treatment and prophylaxis: timing of commencement of dialysis after peritoneal dialysis catheter insertion. Nephrology (Carlton). 2004;9(Suppl 3):S76–7.
136. Dombros N, Dratwa M, Feriani M, Gokal R, Heimburger O, Krediet R, Plum J, Rodrigues A, Selgas R, Struijk D, Verger C. European best practice guidelines for peritoneal dialysis. 3 peritoneal access. Nephrol Dial Transplant. 2005;20(Suppl 9):ix8–ix12.
137. Figueiredo A, Goh BL, Jenkins S, Johnson DW, Mactier R, et al. Clinical practice guidelines for peritoneal access. Perit Dial Int. 2010;30:424–9.
138. Ranganathan D, Baer R, Fassett RG, et al. Randomised controlled trial to determine the appropriate time to initiate peritoneal dialysis after

insertion of catheter to minimise complications (Timely PD study). BMC Nephrol. 2010;11:11.
139. Cheng YL, Chau KF, Choi KS, et al. Peritoneal catheter related complications: a comparison between hemodialysis and intermittent peritoneal dialysis in the break-in period. Adv Perit Dial. 1996;12:231–5.
140. Patel UD, Mottes TA, Flynn JT. Delayed compared with immediate use of peritoneal catheter in pediatric peritoneal dialysis. Adv Perit Dial. 2001;17: 253–9.
141. Ghaffari A. Urgent-start peritoneal dialysis: a quality improvement report. Am J Kidney Dis. 2012;59(3):400–8.
142. Casaretto A, Rosario R, Kotzker WR, Pagan-Rosario Y, Groenhoff C, Guest S. Urgent-start peritoneal dialysis: report from a U.S. private nephrology practice. Adv Perit Dial. 2012;28:102–5.
143. Lobbedez T, Lecouf A, Ficheux M, Henri P, Hurault de Ligny B, Ryckelynck JP. Is rapid initiation of peritoneal dialysis feasible in unplanned dialysis patients? A single-centre experience. Nephrol Dial Transplant. 2008;23(10):3290–4.
144. Moran J, Shapiro M, Ghafferi A, Milligan T, Swanzy K. Urgent-start peritoneal dialysis: a clinical process improvement report. Presented at: 33rd Annual Dialysis Conference; Seattle, WA. 9–12 Mar 2013.
145. McClernon M. Rapid PD start: single-center experience in 30 patients—nursing perspective. Presented at: 33rd Annual Dialysis Conference; Seattle, WA, 2013.
146. Balsera C, Majirsky J, Malone L. Urgent start program: an alternative protocol. Presented at: 33rd Annual Dialysis Conference; Seattle, WA. 2013. – Hartley J. Rapid PD start: single-center experiences in 30 patients—administrator perspective. Presented at: 33rd Annual Dialysis Conference; Seattle, WA, 2013.
147. Jayavelu B, Cohen R, Kumar V. Rapid-start PD: single center experience in 30 patients—clinical perspective. Presented at: 33rd Annual Dialysis Conference; Seattle, WA, 2013.
148. Ludden R. Rapid PD start: single-center experience in thirty patients—renal dietician's perspective. Presented at: 33rd Annual Dialysis Conference; Seattle, WA, 2013.
149. Flanigan S. Rapid PD start: single-center experience in 30 patients—social worker perspective. Presented at: 33rd Annual Dialysis Conference; Seattle, WA, 2013.
150. Povlsen JV, Ivarsen P. How to start the late referred ESRD patient urgently on chronic APD. Nephrol Dial Transplant. 2006;21(Suppl 2):ii56–9.
151. Twardowski ZJ, Nichols WK. Peritoneal dialysis access and exit site including surgical aspects. In: Gokal R, Khanna R, Krediet R, Nolph K, editors. Textbook of peritoneal dialysis. 2nd ed. Dordrecht: Kluwer Academic; 2000. p. 307–61.
152. Ponce SP, Pierratos A, Izatt S, et al. Comparison of the survival and complications of three permanent peritoneal dialysis catheters. Perit Dial Bull. 1982;2:82–6.
153. Francis DMA, Donnelly PK, Veitch PS, et al. Surgical aspects of continuous ambulatory peritoneal dialysis: 3 years experience. Br J Surg. 1984;71:225–9.
154. Ash SR, Daugirdas JT. Peritoneal access devices. In: Daugirdas JT, Blake PG, Ing TS, editors. Handbook of dialysis. Dordrecht: Kluver Academic; 2001. p. 309–43.
155. Scabardi M, Ronco C, Chiaramonte S, Feriani M, Agostini F, La Greca G. Dynamic catheterography in the early diagnosis of peritoneal catheter malfunction. Int J Artif Organs. 1992;15:358–64.
156. Hollett MD, Marn CS, Ellis JH, Francis IR, Swartz RD. Complications of continuous ambulatory peritoneal dialysis: evaluation with CT peritoneography. AJR Am J Roentgenol. 1992;159: 983–9.
157. Cakir B, Kirbas I, Cevik B, Ulu EM, Bayrak A, Coskun M. Complications of continuous ambulatory peritoneal dialysis: evaluation with CT. Diagn Interv Radiol. 2008;14:212–20.
158. Ovnat A, Dukhno O, Pinsk I, Peiser J, Levy I. The laparoscopic option in the management of peritoneal dialysis catheter revision. Surg Endosc. 2002;16: 698–9.
159. Stadermann MB, Rusthoven E, van de Kar NC, Hendriksen A, Monnens LA, Schroder CH. Local fibrinolytic therapy with urokinase for peritoneal dialysis catheter obstruction in children. Perit Dial Int. 2002;22:84–6.
160. Shea M, Hmiel SP, Beck AM. Use of tissue plasminogen activator for thrombolysis in occluded peritoneal dialysis catheters in children. Adv Perit Dial. 2001;17:249–52.
161. Zorzanello MM, Fleming WJ, Prowant BE. Use of tissue plasminogen activator in peritoneal dialysis catheters: a literature review and one center's experience. Nephrol Nurs J. 2004;31:534–7.
162. Dobrashian RD, Conway B, Hutchison A, Gokal R, Taylor PM. The repositioning of migrated Tenckhoff continuous ambulatory peritoneal dialysis catheters under fluoroscopic control. Br J Radiol. 1999; 72:452–6.
163. Savader SJ, Lund G, Scheel PJ, Prescott C, Feeley N, Singh H, Osterman Jr FA. Guide wire directed manipulation of malfunctioning peritoneal dialysis catheters: a critical analysis. J Vasc Interv Radiol. 1997;8:957–63.
164. Jones B, McLaughlin K, Mactier RA, Porteous C. Tenckhoff catheter salvage by closed stiff-wire manipulation without fluoroscopic control. Perit Dial Int. 1998;18:415–8.
165. Gadallah MF, Arora N, Arumugam R, Moles K. Role of Fogarty catheter manipulation in management of migrated, nonfunctional peritoneal dialysis catheters. Am J Kidney Dis. 2000;35:301–5.
166. Korten G, Arendt R, Brugmann E, Klein B. Relocation of a peritoneal catheter without surgical intervention. Perit Dial Bull. 1983;3:46.

167. Hughes CR, Angotti DM, Jubelirer RA. Laparoscopic repositioning of a continuous ambulatory peritoneal dialysis (CAPD) catheter. Surg Endosc. 1994;8(9):1108–9.
168. Zakaria HM. Laparoscopic management of malfunctioning peritoneal dialysis catheters. Oman Med J. 26:171–4. Surg Endosc 2011;8:1108-1109.
169. Cheung CK, Khwaja A. Chylous ascites: an unusual complication of peritoneal dialysis. A case report and literature review. Perit Dial Int. 2008;28:229–31.
170. García Falcón T, Rodríguez-Carmona A, Pérez Fontán M, Fernández Rivera C, Bouza P, Rodríguez Lozano I, et al. Complications of permanent catheter implantation for peritoneal dialysis: incidence and risk factors. Adv Perit Dial. 1994;10:206–9.
171. Levy RI, Wenk RE. Chyloperitoneum in a peritoneal dialysis patient. Am J Kidney Dis. 2001;38:E12.
172. Ramos R, Gonzalez MT, Moreso F, et al. Chylous ascites: an unusual complication of percutaneous peritoneal catheter implantation. Perit Dial Int. 2006;26:722–3.
173. Aalami O, Allen D, Organ C. Chylous ascites: a collective review. Surgery. 2000;128:761–78.
174. Chen J, Lin RK, Hassanein T. Use of Orlistat (Xenical) to treat chylous ascites. J Clin Gastroenterol. 2005;39:831–3.
175. Lee PH, Lin CL, Lai PC, Yang CW. Octreotide therapy for chylous ascites in a chronic dialysis patient. Nephrology. 2005;10:344–7.
176. Geary B, Wade B, Wollman W, El-Galley R. Laparoscopic repair of chylous ascites. J Urol. 2004;171:1231–2.
177. Khanna R, Oreopoulos DG, Dombros N, et al. Continuous ambulatory dialysis after 3 years: still a promising treatment. Perit Dial Bull. 1981;1:24–34.
178. Whiting M, Smith N, Agar JWN. Vaginal peritoneal dialysate leakage per fallopian tubes. Perit Dial Int. 1995;15(1):85.