World J. Surg. 24, 1468–1476, 2000
DOI: 10.1007/s002680010264

WORLD
Journal of
SURGERY

Access Routes for Nutritional Therapy

Dan L. Waitzberg, M.D., Caio Plopper, M.D., Ricardo M. Terra, M.D.

Department of Gastroenterology, University of São Paulo Medical School, R. Maestro Cardim 1175, 01323-001 São Paulo-SP, Brazil

Published Online: November 14, 2000

Abstract. Enteral nutrition (EN) and total parenteral nutrition (TPN) may provide life-sustaining therapy for surgical patients. The duration of nutritional therapy (enteral or parenteral) implies distinct access routes. We review the main aspects related to access routes for nutrient delivery. The enteral route, whenever feasible, is preferred. For EN lasting less than 6 weeks, nasoenteric tubes are the route of choice. Conversely, enterostomy tubes should be used for longer-term enteral feeding and can be placed surgically or with fluoroscopic and endoscopic assistance. The first choice for patients who will not be submitted to laparotomy is percutaneous endoscopic gastrostomy. Postpyloric access, although not consensual, must be considered when there is a high risk of aspiration. For intravenous delivery of nutrients lasting less than 10 days, the peripheral route can be used. However, because of frequent infusion phlebitis, its role is still in discussion. Central venous catheters (CVCs) for TPN delivery may be (1) nonimplantable, percutaneous, nontunneled—used for a few days to 3 to 4 weeks; (2) partially implantable, percutaneous, tunneled—used for longer periods and permanent access; or (3) totally implantable subcutaneous ports—also used for long-term or permanent access. The subclavian vein is usually the insertion site of choice for central venous catheters. Implantable ports are associated with lower rates of septic complications than percutaneous CVCs. The catheter with the least number of necessary lumens should be applied. Central venous nutrient delivery can also be accomplished through peripherally inserted central catheters, which avoid insertion-related risks.

Enteral nutrition (EN) and total parenteral nutrition (TPN) provide life-sustaining therapy for patients who cannot achieve an adequate level of nutritional intake orally and who consequently are at risk for malnutrition and its effects. The choice of the best feeding route is essential for making ends meet in the nutritional therapy. The aim of this paper is to review the algorithms for indications of various gastrointestinal and intravenous access routes for nutrient delivery.

Choosing the Feeding Route

Once a patient is a candidate for specialized nutritional support (EN or TPN), the first decision is whether the nutrients will be delivered to the gastrointestinal tract or intravenously.

Correspondence to: D.L. Waitzberg, M.D., e-mail: d.waitzberg@zaz.com.br

Is the Digestive Tract Functional?

A highly beneficial modality when properly indicated, TPN imposes high economic costs and is associated with a wide range of complications, such as liver dysfunction and cholestasis, septic and metabolic complications, complications related to the technique of inserting intravenous catheters, and, lately recognized, gut mucosal atrophy and barrier rupture leading to bacterial translocation [1, 2, 3].

On the other hand, gastrointestinal delivery of nutrients (EN) is a more physiologic pathway and is thought to improve the status of the gut immune system and maintain the normal gut architecture and microflora [4]. Experimental studies show that the presence of some specific nutrients in the gastrointestinal lumen is essential to the maintenance of enterocyte morphology and function [4]. Several randomized controlled studies have demonstrated that enteral feeding, compared to TPN, leads to a significantly lower incidence of septic complications in surgical patients [5, 6]. Therefore whenever the gastrointestinal tract function is preserved, the enteral route is the first choice for nutritional therapy.

How Long Will the Patient Require Nutritional Support?

Whenever a surgical patient is assigned to enteral or parenteral nutritional support, the length of time for which it will be needed must be predicted for choosing the best access route. It is accepted that if a patient is assigned for preoperative nutritional support it should last an average of 10 days to permit adequate improvement of the nutritional status. Similarly, postoperative artificial nutrition must last more than 7 days to be effective [7]. If the enteral route is chosen, the duration, even though usually difficult to predict, must be established, particularly if the patient is a candidate for abdominal surgery, as feeding tube placement can often be accomplished safely during laparotomy. Although not consensual, a 6-week period usually distinguishes short-term from long-term enteral feeding [8].

Generally, short-term enteral feeding is achieved through placement of nasoenteric feeding tubes (with gastric, duodenal or jejunal position). Some have demonstrated the efficacy and safety of enteral feeding through nasoenteric tubes for longer periods

[9]. It is still widely accepted that long-term enteral feeding should be accomplished through either gastrostomy or jejunostomy feeding tubes, as the presence of a nasoenteric tube can lead to late complications, including migration of the tube (especially into the esophagus), pulmonary aspiration of infused solutions, lesions of the gastrointestinal (GI) tract mucosa by the tip of the tube, ear and nose infections, esophageal stricture, and vocal cord and pharyngeal paralysis [10, 11]. On the other hand, gastrostomy and jejunostomy tubes function well in the long term with no significant complications [12]. Most of the complications associated with these feeding tubes are related to the insertion techniques rather than to their long-term use.

When the patient is assigned to parenteral nutrition, the period during which it will be required is also one of the primary decisions for the choice of the venous access device and insertion site. There are three categories of central venous access devices to be considered: (1) nonimplantable, nontunneled, percutaneously placed catheters, used for short-term parenteral nutrition (a few days to 3–4 weeks); (2) partially implantable, tunneled catheters; and (3) totally implantable venous access devices. The latter two are used for longer periods (1–3 months and longer) and permanent access [13]. Some advocate the use of peripheral venous access for parenteral feeding as the first option for medically stable patients who require intravenous feeding for short periods (less than 10–14 days) because it avoids the risks of central venous catheterization [14, 15]. However, peripheral parenteral nutrition (PPN) solutions' osmolality cannot exceed 700 mOsm, with a significantly lower dextrose concentration (up to 15%), making it more difficult to achieve the patient's caloric demands. Moreover, peripheral access sites must be changed frequently to avoid phlebitis and infiltration of the PPN solution into the subcutaneous tissue, limiting the widespread application of this access.

Gastrointestinal Access

Once the enteral route is chosen and the decision about a nasoenteric tube or tube enterostomy is made, the next decision is whether the tip of the feeding tube is placed in the stomach, duodenum, or jejunum.

Is the Patient at High Risk of Pulmonary Aspiration?

The possible risk of pulmonary aspiration is the most commonly used criterion to determine the postpyloric position of the tip of the feeding tube. This risk increases significantly in the presence of neurologic deficits, esophageal disorders, head and neck cancers, high gastric residuals, gastric outlet obstruction, and gastroparesis [1, 16].

There are no conclusive data to support the relation between intragastric feeding and pulmonary aspiration [17]. In a review of 45 papers that tried to address this issue in patients with severe neurogenic oropharyngeal dysphagia, Lazarus et al. concluded that, mainly because of poorly defined populations and methodologic flaws, there was insufficient evidence to support the idea that aspiration is increased with intragastric feeding compared to postpyloric feeding [17]. In neurologic patients no significant differences were found between intragastric or postpyloric enteral feedings in terms of days to achieve full feeding, ventilator days, intensive care unit length of stay, or the incidence of pneumonia or aspiration [18]. Despite the lack of conclusive data, most physicians tend to use postpyloric tip feeding tubes in high risk patients, although it does not eliminate the risk of feeding-related pulmonary aspiration.

Nasoenteric Feeding Tubes

Nasoenteric feeding is the least expensive and most widely used modality of enteral nutrition. Nasoenteric tube placement, usually a bedside procedure, can be manual or performed with endoscopic or fluoroscopic assistance [1, 19, 20]. The correct position of the feeding tube tip must be thoroughly verified by means of several procedures, such as hearing air injected through the tube, withdrawal of enteral juices, or measuring the pH. In patients with neurologic impairment, coma, absence of cough reflex, old age, chronic pulmonary disease, or myasthenia gravis and always when there is not absolute certainty of correct tube placement, it must be radiographically verified prior to initiating diet infusion. In patients with intact GI architecture and function and without a high risk of aspiration and gastroesophageal reflux, nasogastric intubation is the least expensive and easiest way to gain enteral feeding access, as endoscopy and fluoroscopy are not required.

Postpyloric tube placement is most easily accomplished during laparotomy [21]. However, it can be effectively done applying manual techniques, such as the one described by Rujeles. The efficacy of an intravenous bolus of metoclopramide to facilitate duodenal placement is controversial [22]. The feeding tube can also be placed with endoscopic assistance, using either the guidewire or pull-along method. For the first, a guidewire is placed in the small bowel through the biopsy channel; the endoscope is then withdrawn, and a flexible feeding tube is passed over the guidewire. With the pull-along method, a suture is attached to the tip of the feeding tube, grasped by the biopsy forceps, and then moved to a postpyloric position [20]. Patrick et al. reported a success rate of 94% with these procedures at the bedside in 54 critically ill patients [23]. In a study of 41 endoscopically placed feeding tubes, Stark et al. achieved success rates of 93% with the pull-along technique and 94% using the guidewire method, associated with fluoroscopy. With fluoroscopy alone, the reported success rate was 56% [20].

Postpyloric nasoenteric tube placement can also be achieved guided by fluoroscopy with a long guidewire. Applying this method, Gutierrez and Balfe obtained a success rate of 86% in 882 attempts, having only four major complications (three fatal arrhythmias and one tracheobronchial injury) [19]. Using the same approach, Ott et al. and Prager et al. achieved successful postpyloric placement in 90.4% and 95% of cases, respectively [24]. This is a safe, easily performed, highly successful procedure, but it requires changes in the patient's position that may not be feasible for the critically ill.

Although rare, complications from the introduction of nasoenteric feeding tubes have been described. They include pneumothorax, hydrothorax, empyema, mediastinitis, pneumonia, esophageal perforation, dental injury, gastric bleeding and perforation, tracheobronchial injury, and fatal arrhythmias [8, 19].

Cervical Pharyngostomy/Esophagostomy

In 1951 passage of a feeding tube through the pharynx to allow safe feeding of patients with cancers of the upper aerodigestive tract and swallowing disorders was described [25]. Another pos-

sible alternative for surgical pharyngostomy is percutaneous needle pharyngostomy, an over-the-wire technique that can be performed at the bedside under local anesthesia [26]. Cervical esophagostomy with funneling under skin flaps can also be performed during conservation pharyngeal and laryngeal surgery for placing a feeding tube. An abdominal esophagostomy was also described for feeding tube placement in children with long gap esophageal atresia, for whom the decision to replace the esophagus was made [27].

Gastrostomy

Gastrostomy feeding tubes may be placed via open surgical procedures or percutaneously using endoscopic, radiologic, or laparoscopic techniques. The first choice for surgical patients who will not be submitted to laparotomy is percutaneous endoscopic gastrostomy (PEG). This fast, easy procedure can be done with local anesthesia at the bedside; it has low morbidity rates and permits early initiation of enteral feeding [28]. Relative contraindications include previous upper abdominal surgery, obesity, and bleeding disorders. Ascites and portal hypertension are considered absolute contraindications [1], although, some authors reported that increased experience with the technique has allowed acceptable results in patients with ascites and previous gastric surgery [29, 30].

There are three techniques for PEG introduction: the "pull" method, the "push" method, and the introducer method. Each starts with an esophagogastroduodenoscopy to rule out any abnormal condition that could preclude its use [8]. With the "pull" method, the abdominal wall is punctured with a Seldinger needle after transillumination by the endoscope. A guidewire is then introduced, and its tip is grasped by a biopsy snare and drawn out of the patient's mouth. The feeding tube is then attached to the guidewire tip and pulled out of the patient's abdominal wall and secured to the skin by a disk. The "push" method is similar, with a much longer feeding tube being pushed along the guidewire until it reaches its final position. With these two techniques the proper intragastric position of the assembly is confirmed by endoscopy [31]. With the introducer method, after placement of an intragastric guidewire, a 16F dilator with a peel-away introducer is passed over it. The dilator then removed, and a gastrostomy tube is placed through the introducer as it is peeled away. The feeding tube is fixed intragastrically by an internal balloon [32].

A variety of complications from PEG insertion have been reported, such as feeding tube dislodgment, bleeding, aspiration, tube-site infection, persistent gastric fistula, and metastatic head and neck cancer to the PEG exit site [33, 34, 35]. In a series of 135 patients who required insertion of a PEG feeding tube (101 by the introducer method and 34 by the pull-through method), Petersen and Kruse found a 32% overall complication rate (including tube dysfunction) and a 13% rate of serious complications (intraperitoneal leakage, wound infection, and subcutaneous emphysema, each of which occurred after the introducer technique), with 4% mortality [36]. Low body mass index and advanced malignancies were reported by Amann et al. to be predictors of complications in patients submitted to PEG application [37]. Unfortunately, these access procedures were generally performed in critically ill or elderly patients who have a poor prognosis. Early PEG installation in these patients should help prevent further nutritional deterioration and the related complication risk, increasing the probability of survival [8, 37].

Open surgical gastrostomy is still a widely used procedure for insertion of feeding tubes. The Stamm technique is the most frequently applied method of gastrostomy insertion. Another alternative is surgical placement of gastrostomy tubes through a laparoscopic procedure. Edelman et al. described a technique in 20 patients in which the stomach is brought up to the abdominal wall with a grasper and attached to it through Cope suture anchors. A needle is then placed through the abdominal wall to the stomach, and a guidewire and dilators are passed through it to allow passage of the feeding tube [38].

Many have compared the cost-effectiveness of open, percutaneous endoscopic and laparoscopic gastrostomies. Several studies reported that PEG is a less expensive, faster procedure and is associated with lower morbidity and mortality rates than open gastrostomy [39, 40]. However, in a study of 88 patients who underwent PEG or surgical gastrostomy, Apelgren and Zambos reported that PEG, although more cost-effective, was associated with a significantly higher intraoperative morbidity rate [41].

In a comparative study of 17 patients submitted to PEG or laparoscopic gastrostomy (LG) insertion, Edelman et al. found that LG had similar operating times and similar morbidity and mortality rates. Hence it was a suitable, safe procedure for patients with head and neck tumors and intrathoracic pathologies that prevent PEG insertion [42].

Jejunostomy

Jejunostomy access is achieved using the same basic methods as gastrostomy, with some technical modifications to accommodate jejunal placement. As with gastrostomies, jejunostomies can be placed surgically, endoscopically (PEJ), or laparoscopically. Furthermore, it can be achieved using a fluoroscopically assisted technique. The most frequent complications of jejunostomies are tube dislodgment, aspiration events, and occlusion [43]. Moreover, a distinctly uncommon but critical consequence of the use of jejunostomy tubes is the development of small bowel ischemia and necrosis during the immediate postoperative period [44].

Open surgical jejunostomy is usually performed using the Witzel technique. Another alternative for open surgical jejunostomy is the needle-catheter jejunostomy (NCJ), in which a purse-string suture is placed in the jejunal loop wall and a large-bore needle is tunneled subserosally before entering the lumen. A catheter is then inserted through the needle, which is removed; the purse-string suture is tied, and the catheter is exteriorized through the abdominal wall by a second large-bore needle. PEJ feeding tubes can be placed by a direct technique with a 160 cm endoscope [45] or an indirect technique through a previous PEG [46].

Fluoroscopic methods have been used by radiologists to gain postpyloric access. Two distinct methods are used for this purpose. In the first one, a catheter is inserted through a previous gastrostomy and passed along to the jejunum with a guidewire under fluoroscopic guidance [47]. In the other method, a 21-gauge needle is inserted into the jejunal lumen previously distended with air. Prior to this puncture, the anatomy must be delineated using both ultrasonography and fluoroscopy [48].

Some techniques have been described for laparoscopically assisted placement of jejunostomy feeding tubes [49, 50]. Some have described a technique of percutaneous jejunostomy placement,

inserting a needle into the jejunal lumen during laparoscopy [51]. In a series of 81 consecutive patients undergoing laparoscopically assisted jejunostomy, Murayama et al. found a major complication rate of 8% that included GI bleeding, wound infection, and failed placement. They concluded that these procedures are safe and should be considered for patients in whom endoscopy is not feasible or undesirable or who are undergoing other surgical procedures [52].

Intravenous Access

Central Venous Catheters

Whenever the parenteral route is chosen for delivery of nutrients, the type of intravenous access device, the catheter design, and its site of insertion must be determined.

Type of Catheter. There are three classes of the central venous catheter (CVC) available for clinical use: percutaneous CVCs, chronic indwelling CVCs, and implantable ports. The choice of CVC is determined by the length of therapy.

Percutaneous CVCs, used for short-term PN, present relative ease for insertion and removal but require frequent sterile dressing changes and heparin flushes into every lumen; they are more prone to infectious complications and limit patient mobility and activities [13]. Catheters designed for percutaneous insertion are usually made of polyurethane, a stiff material that softens in response to body temperature [53].

Chronic indwelling CVCs, such as Broviac, Hickman, and Groshong catheters, are usually the device of choice when a catheter is needed for 1 to 3 months or longer. In contrast to percutaneous CVCs, they are more often made of silicone rubber or, less frequently, polyurethane. Indwelling catheters are placed surgically and tunneled subcutaneously, creating a physical barrier to bacterial infection [54]. Indwelling tunneled CVCs usually have a Dacron cuff that allows tissue ingrowth and promotes local fibrosis within 2 to 6 weeks, which helps prevent bacterial migration and catheter dislodgment [13].

Another, newer alternative to the vascular access devices above is the totally implantable venous access disk (IVAD), which eliminates the external catheter portion and the need for daily heparin flushes. These devices consist of a steel, titanium, or plastic port covered by a Silastic septum and a Silastic catheter. The use of these implantable ports is contraindicated in obese patients if the port is difficult to palpate. Two of the commercially available IVADs frequently used are the Port-A-Cath and the Cordis Miniport; they differ in terms of size and weight (16.0 and 3.8 g, respectively). Lilienberg et al. (1994) collected the opinions of patients and nurses about these two devices; they reported that Port-A-Cath was considered the easiest system for needle insertion and that the needle was thought to be more secure. The Cordis Miniport was preferred for cosmetic reasons [55].

The IVADs are usually placed with the patient in the operating room. A small incision is made, the port is sutured in a subcutaneous pocket, and the catheter is tunneled to the chosen vein [13]. Some authors have reported good results with sonographically and fluoroscopically guided placement of IVADs by interventionist vascular radiologists. In a series of 541 patients, Carrera-Villamor et al. achieved 98% technical success, defined as implanting the catheter; immediate complications (pneumothorax, accidental carotid arterial puncture, catheter misplacement, vein spasm) occurred in 6.8% [56].

The main differences between implantable ports and external CVCs are the lower infectious complication rates, the requirement for only monthly heparin flushes, and the better patient mobility, allowing unrestricted activity except contact sports [13, 57]. Several trials comparing the infection rates between permanent external CVCs and implantable ports have reported fewer and later infectious complications with the latter (Table 1). Furthermore, Mirro et al. reported a longer failure-free duration of implantable ports than externalized Hickman and Broviac catheters (failure was defined as removal of the catheter due to infection, obstruction, or dislodgment) [60]. On the other hand, implantable ports require more complex and costly insertion and removal procedures than external CVCs and repetitive needle punctures for access; they also have a limited lifetime, usually 1000 to 2000 punctures [54]. Children, particularly those under 11 to 12 years of age, may experience a great deal of anxiety before these punctures [61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102].

Catheter Design. Many advocate that the use of multiple-lumen CVCs should be avoided for parenteral nutrition whenever possible, as they are associated with a higher risk of catheter-related infection [13, 67–69]. However, clinical trials that addressed this question in patients receiving TPN or other intravenous therapies reported conflicting results, as shown in Table 2. The clinical utility of these multiple-lumen CVCs has been widely accepted, as a large number of chronically or critically ill patients require intravenous therapies other than TPN, in addition to central venous pressure monitoring; and no difference between these two catheter classes has been solidly confirmed [72]. Moreover, fewer patients with multiple-lumen CVCs require peripheral venous access than patients with single-lumen CVCs. According to Johnson and Rypins, parenteral nutrition can be given as safely via double-lumen catheters as single-lumen catheters when rigid care protocols are established and followed [73]. However, it is still the consensus that TPN should be delivered through an exclusive catheter lumen and that the catheter with the fewest necessary lumens should be selected.

Recently, another option was created with the impregnation of CVCs with antiseptic materials, such as silver sulfadiazine and chlorhexidine, in an attempt to prevent bacterial colonization and therefore reduce the rate of septic complications. Many studies have been conducted to determine if the usage of these specially coated catheters effectively reduced the septic complication rates of CVCs. Five prospective randomized trials compared silver sulfadiazine and chlorhexidine-coated CVCs with regular CVCs for administration of TPN or other intravenous therapies. Two of them reported decreased colonization of the catheter tip and intradermal segments with antiseptic-coated CVCs, but none found any significant differences between these two devices in terms of catheter-related septicemia [75–79].

Site of Insertion. Numerous venous access sites have been used for central administration of parenteral nutrition. The most commonly used are the subclavian and internal jugular and less frequently the femoral vein [80]. A number of other sites, such as the

Table 1. Infectious complications with permanent CVCs and implantable ports.

Trial	Year	Design	No.	Results	*p*
Ross [58]	1988	Prospective	41 Ports 50 External	Total infections: 15 (external), 7 (ports)	<0.01
Mirro [59]	1989	Prospective	286 External 82 Ports	Ports remained infection-free longer	<0.01
Mirro [60]	1990	Retrospective	266 External 93 Ports	Ports remained infection-free longer	0.014
Ingram [61]	1991	Prospective cohort	144 External 140 Ports	Infections per 1000 days: 4.3 (external) vs. 0.7 (ports)	<0.001
Mueller [62]	1992	Randomized	46 External 46 Ports	Infections per 1000 days: 1.6 (external) vs. 1.2 (ports)	NS
Pegues [63]	1992	Retrospective	47 External 94 Ports	Infections per 1000 days: 1.8 (external) vs. 0.4 (ports)	<0.0002
Keung [64]	1994	Retrospective	15 External 42 Ports	Infections per 1000 days: 1.3 (external) vs. 0.9 (ports)	NS
Muscedere [65]	1998	Retrospective	23 External 29 Ports	Time until infection (mean days): 96 (external) vs. 184 (ports)	<0.001

(Modified from Shapiro et al. [66], with permission.)
CVCs: central venous catheters.

Table 2. Comparison of septic complications between single-lumen and multilumen CVCs.

				Rate of infections (%)		
Trial	Year	Design	No.	Single-lumen	Multi-lumen	*p*
McCarthy [67]	1987	Prospective, randomized	36 (single) 39 (triple)	0	12.8	0.055 (NS)
Rose [70]	1988	Retrospective	252 (single) 244 (triple)	1.6	4.9	0.065 (NS)
Shulman [71]	1988	Retrospective	30 (single) 31 (double)	57.0	52.0	NS
Gil [72]	1989	Prospective	63 (single) 157 (triple)	7.9	3.8	NS
Early [68]	1990	Retrospective	51 (single) 94 (double)	14.0	21.0	0.02
Johnson [73]	1990	Prospective, randomized	48 (single) 53 (double)	0	0	NS
Clark-Christoff [69]	1992	Prospective, randomized	78 (single) 99 (triple)	2.6	13.1	<0.01
Farkas [74]	1992	Prospective, randomized	68 (single) 61 (triple)	8.9	11.5	NS

inferior vena cava and the ovarian and external iliac veins have been described [81–83].

Many studies have been conducted to associate the venous access site for TPN with the complication rate, particularly the infectious complications. The subclavian vein is accepted as the insertion site of choice for TPN catheters, providing ready access with the shortest tunnel distance until venous entry, a low rate of septic complications, and high tolerance by the patients [13]. Whenever the subclavian route is not feasible, the internal jugular vein offers a ready access alternative that avoids mechanical complications such as pneumothorax. However, it is associated with higher infectious rates and more difficulty maintaining sterile dressings than the latter [84].

The femoral vein route has been indicated as an alternative route when the superior vena cava system cannot be accessed, such as for patients with thrombosis of the subclavian or internal jugular veins, upper torso burns, mediastinal radiation therapy, cervicothoracic trauma, bilateral radical dissection of the neck, or infected median sternotomy incisions [85]. The femoral and saphenous veins have been used increasingly, particularly in infants [86, 87]. In this population, placing a Broviac catheter in the greater saphenous or femoral vein with a subcutaneous tunnel for the catheter to exit on the anterior abdominal wall or the distal thigh has been applied extensively with good results [86, 87].

Many have reported unacceptably high rates of septic complications associated with femorally inserted CVCs [80, 85]. Purdue and Hunt supported use of the femoral route for short-term TPN, with lower complication rates [88]. However, it required rigid catheter care protocols, with three daily dressing changes and catheter replacement every third day, making it costly and not feasible for normal hospital environments [80]. If none of the above is feasible, translumbar percutaneous inferior vena cava insertion can be tried [81].

Peripheral veins, such as the cephalic and basilic veins, are also an option for inserting implantable [peripheral access systems (PAS) ports] and nonimplantable [peripherally inserted central catheters (PICCs)] venous catheters with centrally placed tips. Numerous studies have shown that PICC and PAS ports are appropriate for short- and long-term use; catheter life ranges from 10 days to several months [89, 90, 91]. These devices present lower

insertion-related costs and complications, lower infection rates, and easier removal than central venous catheters and ports, providing an attractive alternative whenever a chest-placed device is inappropriate or undesired [89]. Conversely, their use requires an intact peripheral venous system and frequent heparin flushes and sterile dressing changes; it imposes restricted flow rates, presents the difficulty of withdrawing blood if the lumen is too small, and high rates of local thrombophlebitis [92]. Polak et al. reported high rates of patient tolerance and satisfaction with the use of the PICC, particularly when it was placed above the elbow. The perception of low interference with daily activities was positively associated with the patient's willingness to receive another PICC in the future [93].

Peripheral Access

Parenteral nutrition delivered through a peripheral vein has been advocated by many as a substitute for central venous TPN in an attempt to diminish its related risks and costs [94]. It is well established that peripheral venous delivery of hypocaloric and protein-sparing parenteral nutrition solutions is a successful measure for surgical patients with moderate malnutrition [95].

Peripheral vein thrombophlebitis (PVT) is by far the most frequent complication associated with this modality of parenteral nutrition, which causes thrombosis, erythema, pain, local edema, and extravasation of infused solutions [96]. A large number of studies have contributed to the understanding of the etiology and pathophysiology of PVT, leading to the establishment of a series of preventive measures to reduce its incidence. The factors most importantly associated with PVT are infusate osmolality, cannula size and material, trauma at venipuncture, and duration of infusion [97, 98, 99].

A number of efficient measures have been demonstrated to reduce the incidence of peripheral parenteral nutrition complications. They include dilution of infused solutions, use of compounded mixtures instead of separate infusion bottles, continuous administration of fat emulsions, use of glycerol as an energy source, use of transdermal glyceryl trinitrate, rotation of insertion sites, infusion of buffering substances, use of heparin or hydrocortisone (or both), and the use of ultrafine short cannulas [96, 97, 98100, 101, 102, 103]. Hecker reported a series of meta-analyses to determine the relative importance of infusate buffering, additive heparin and hydrocortisone, topical glyceryl trinitrate, and the use of in-line filters for the reduction of PVT in patients receiving peripheral parenteral nutrition. Each measure significantly reduced infusion failure; the most effective were corticosteroids (50%), heparin and filters (40%), buffering (35%), glyceryl trinitrate (30%), and heparin combined with corticosteroids (about 20%) [104].

Application of the above measures has led to increasing use and acceptance of peripheral parenteral nutrition. However, the introduction of these pharmacologic procedures must be evaluated carefully, as addition of any drug to parenteral nutrition solutions must fulfill a number of stability criteria. Furthermore, the drugs administered to diminish the PVT rate have a systemic effect, and no well conducted study has yet assessed the adverse effect profile of this drug association during parenteral nutrition [94]. Thus the feasibility of the peripheral venous route as the first choice for parenteral nutrition administration in surgical patients has not reached a consensus.

Résumé

La nutrition entérale (NE) et parentérale totale (NPT) sont vitales pour les patients en chirurgie. La durée prolongée de la thérapie nutritionnelle (soit entérale ou parentérale) implique des voies d'abord distincts. Les auteurs passent en revue les aspects principaux de ces voies d'accès pour la nutrition artificielle. La route entérale est préférée chaque fois que possible. Pour la NE de durée de moins de 6 semaines, le tube nasogastrique est la voie d'accès de préférence. A l'inverse, si on prévoit une alimentation de plus longue durée, il faut préférer un tube placé au-delà de l'estomac, soit chirurgicalement avec guidance radioscopique ou endoscopiquement. Pour les patients qui n'ont pas besoin d'une laparotomie, la gastrostomie percutanée par voie endoscopique représente la voie de référence. Bien qu'il n'existe pas de consensus, un accès au tube digestif post-pylorique pourrait être une alternative lorsque le patient présente un haut risque d'inhalation. En ce qui concerne l'alimentation qui doit durer moins de 10 jours, une simple voie d'abord périphérique peut être envisagée. Cependant, en raison de la fréquence élevée de phlébite au niveau du site d'infusion, son rôle est toujours sujet de discussion. Le cathéter central (CC) utilisé pour la NTP peut être temporaire, placé en percutané, sans tunnelisation, utilisé entre quelques jours et 3 à 4 semaines; partiellement implantable, tunnelisé, utilisé pendant des périodes de temps plus longues et enfin, parfois, permanent. La veine sous-clavière est le site d'insertion préféré d'un CC. Les ports implantables (port-à-cath) sont associés à un risque d'infection plus bas que les CC percutanés. Il faut employer des cathéters avec le moins de lumières possibles. On peut aussi utiliser des CC insérés à travers une veine périphérique, ce qui minimise les risques en rapport avec le site d'insertion.

Resumen

La nutrición enteral (NE) y la nutrición parenteral (NP) son terapias con capacidad de mantener la vida en el paciente quirúrgico. La duración de la terapia nutricional, sea enteral o parenteral, implica diversidad en las rutas de acceso. Los autores revisan los principales aspectos pertinentes a las rutas de acceso para la provisión de nutrientes. La ruta enteral, cuando es factible, debe ser la preferida. Para regímenes de NE de menos de 6 semanas, las sondas nasoentéricas representan la mejor ruta. Por el contrario, los tubos de enterostomía están indicados en la NE de larga duración; éstos pueden ser colocados por intervención quirúrgica o con ayuda fluoroscópica o endoscópica. El procedimiento de escogencia en pacientes que no van a ser sometidos a laparotomía es la gastrostomía percutánea endoscópica. El acceso post-pilórico, aunque no hay consenso al respecto, puede ser considerado en pacientes con alto riesgo de aspiración. Se puede utilizar la ruta periférica cuando la provisión intravenosa de nutrientes sea por menos de 10 días. Sin embargo, esta vía es motivo de discusión por razón de la alta incidencia de flebitis. Los catéteres venosos centrales (CVCs) para proveer NPT, de tipo no implantable, percutáneo no tunelizado, pueden ser usados desde unos pocos días hasta 3–4 semanas; los catéteres percutáneos parcialmente implantables y tunelizados son utilizados por períodos más largos y son de acceso permanente; los portales subcutáneos totalmente implantables también son utilizados en regímenes de larga duración y como acceso

permanente. La vena subclavia es usualmente la de elección para colocar CVCs. Los portales implantables resultan en menores tasas de complicaciones sépticas que los CVCs percutáneos. Se deben utilizar catéteres con el menor número de vías. La provisión de nutrientes por vena central también puede hacerse por catéteres centrales de inserción periférica, ésto con el propósito de disminuir los riesgos inherentes a la inserción. Infectious complications with permanent CVCs and implantable ports. Comparison of septic complications between single-lumen and multilumen CVCs.

References

1. Sax, H.C., Souba, W.W.: Enteral and parenteral feedings: guidelines and recommendations. Med. Clin. North Am. *77*:863, 1993
2. Sitges-Serra, A., Puig, P., Jaurrieta, E.: Catheter-related sepsis during parenteral nutrition. Surgery *93*:479, 1983
3. Khan, J., Iiboshi, Y., Nezu, R., Chen, K., Cui, L., Yoshida, H., Wasa, M., Fukuzawa, M., Kamata, S., Takagi, Y., Okada, A.: Total parenteral nutrition increases uptake of latex beads by Peyer's patches. J.P.E.N. *21*:31, 1997
4. Swank, G.M., Deitch, E.A.: Role of the gut in multiple organ failure: bacterial translocation and permeability changes. World J. Surg. *20*:411, 1996
5. Kudsk, K.A., Croce, M.A., Fabian, T.C., Minard, G., Tolley, E.A., Poret, A., Kuhl, M.R., Brown, R.O.: Enteral versus parenteral feeding: effects on septic morbidity after blunt and penetrating abdominal trauma. Ann. Surg. *215*:503, 1992
6. Moore, F.A., Feliciano, D.V., Andrassy, R.J., McArdle, A.H., Booth, F.V., Morgenstein-Wagner, T.B., Kellum, J.M., Jr., Welling, R.E., Moore, E.E.: Early enteral feeding, compared with parenteral, reduces postoperative septic complications: the results of a meta-analysis. Ann. Surg. *216*:127, 1992
7. Recommandations du jury. Nutr. Clin. Metabol. *9*:233, 1995
8. Minard, G.: Enteral access. Nutr. Clin. Pract. *9*:172, 1994
9. Fay, D.E., Poplausky, M., Gruber, N., Lance, P.: Long-term enteral feeding: a retrospective comparison of delivery via percutaneous endoscopic gastrostomy and nasoenteric tubes. Am. J. Gastroenterol. *86*:1604, 1991
10. Shike M.: Enteral feeding. In: Modern Nutrition in Health and Disease, 8th edition, Shils, M.E., Olson, J.A., Shike, M., editors, Philadelphia, Lea & Febiger, 1994, pp. 1471–1429
11. Sofferman, R.A., Haisch, C.E., Kirchner, J.A., Hardin, N.J.: The nasogastric tube syndrome. Laryngoscope *100*:962, 1990
12. Shike, M., Berner, Y.N., Gerdes, H., Gerold, F.P., Bloch, A., Sessions, R., Strong, E.: Percutaneous endoscopic gastrostomy and jejunostomy for long-term feeding in patients with cancer of the head and neck. Otolaryngol. Head Neck Surg. *101*:549, 1989
13. Labow, C.A.: Venous access device options. Surg. Oncol. Clin. North Am. *4*:473, 1995
14. Rombeau J.L.: Enteral nutrition. In: Cecil Textbook of Medicine, 20th edition, Bennett, J.C., Plum, F., editors, Philadelphia, Saunders, 1996, pp. 1168–1171
15. Payne-James, J.J., Khawaja, H.T.: First choice for total parenteral nutrition: the peripheral route. J.P.E.N. *17*:468, 1993
16. Lipman, T.O., Cass, O.W., Ho, C.S., Kearns, P.J., Shikora, S.A.: Group I: choosing the appropriate method of placement of an enteral feeding tube in the high risk population. Nutr. Clin. Pract. *12*:S54, 1997
17. Lazarus, B.A., Murphy, J.H., Culpepper, L.: Aspiration associated with long-term gastric versus jejunal feeding: a critical analysis of the literature. Arch. Phys. Med. Reabil. *71*:46, 1990
18. Spain, D.A., DeWeese, R.C., Reynolds, N.A., Richardson, J.D.: Transpyloric passage of feeding tubes in patients with head injuries does not decrease complications. J. Trauma *39*:1100, 1995
19. Gutierrez, E.D., Balfe, D.M.: Fluoroscopically-guided nasoenteric feeding tube placement: results of a 1-year study. Radiology *178*:759, 1991
20. Stark, S.P., Sharpe, J.N., Larson, G.M.: Endoscopically placed naso-enteral feeding tubes: indications and techniques. Am. Surg. *57*:203, 1991
21. Jensen, G.L., Sporay, G., Whitmire, S., Taraszewski, R., Reed, M.J.: Intraoperative placement of the nasoenteric feeding tube: a practical alternative? J.P.E.N. *19*:244, 1995
22. Kittinger, J.W., Sandler, R.S., Heizer, W.D.: Efficacy of metoclopramide as an adjunct to duodenal placement of small-bore feeding tubes: a randomized, placebo-controlled, double-blind study. J.P.E.N. *11*:33, 1987
23. Patrick, P.G., Marulendra, S., Kirby, D.F., DeLegge, M.H.: Endoscopic nasogastric-jejunal feeding tube placement in critically ill patients. Gastrointest. Endosc. *45*:72, 1997
24. Ott, D.J., Mattox, H.E., Gelfand, D.W., Chen, M.Y., Wu, W.C.: Enteral feeding tubes: placement by using fluoroscopy and endoscopy. A.J.R. *157*:769, 1991
25. Clevenger, F.W., Rodriguez, D.J.: Decision-making for enteral feeding administration: the why behind where and how. Nutr. Clin. Pract. *10*:104, 1995
26. Bucklin, D.L., Gilsdorf, R.B.: Percutaneous needle pharyngostomy. J.P.E.N. *9*:968, 1985
27. Bhatnagar, V., Agarwala, S., Chattopadhyay, A., Mitra, D.K.: Exteriorization of the distal esophagus in the abdomen in esophageal atresia. J. Pediatr. Surg. *33*:489, 1998
28. McCarter, T.L., Condon, S.C., Aguillar, R.C., Gibson, D.J., Chen, Y.K.: Randomized prospective trial of early versus delayed feeding after percutaneous endoscopic gastrostomy placement. Am. J. Gastroenterol. *93*:419, 1998
29. Lee, M.J., Saini, S., Brink, J.A., Morrison, M.C., Hahn, P.F., Mueller, P.R.: Malignant small bowel obstruction and ascites: not a contraindication to percutaneous gastrostomy. Clin. Radiol. *44*:332, 1991
30. Stellato, T.A., Gauderer, M.W., Ponsky, J.L.: Percutaneous endoscopic gastrostomy following previous abdominal surgery. Ann. Surg. *200*:46, 1984
31. Hogan, R.B., DeMarco, D.C., Hamilton, J.K., Walker, C.O., Polter, D.E.: Percutaneous endoscopic gastrostomy: to push or to pull? A prospective randomized trial. Gastrointest. Endosc. *32*:253, 1986
32. Russell, T.R., Brotman, M., Norris, F.: Percutaneous gastrostomy: a new simplified and cost-effective technique. Am. J. Surg. *142*:132, 1984
33. Larson, D.E., Burton, D.D., Schroeder, K.W., DiMagno, E.P.: Percutaneous endoscopic gastrostomy: indications, success, complications, and mortality in 314 consecutive patients. Gastroenterology *93*:48, 1987
34. Grant, J.P.: Percutaneous endoscopic gastrostomy: initial placement by single endoscopic technique and long-term follow-up. Ann. Surg. *217*:168, 1993
35. Schneider, A.M., Loggie, B.W.: Metastatic head and neck cancer to the percutaneous endoscopic gastrostomy exit site: a case report and review of the literature. Am. Surg. *63*:481, 1997
36. Petersen, T.I., Kruse, A.: Complications of percutaneous endoscopic gastrostomy. Eur. J. Surg. *163*:351, 1997
37. Amann, W., Mischinger, H.J., Berger, A., Rosanelli, G., Schweiger, W., Werkgartner, G., Fruhwirth, J., Hauser, H.: Percutaneous endoscopic gastrostomy (PEG): 8 years of clinical experience in 232 patients. Surg. Endosc. *11*:741, 1997
38. Edelman, D.S., Arroyo, P.J., Unger, S.W.: Laparoscopic gastrostomy or percutaneous endoscopic gastrostomy. Contemp. Surg. *44*:269, 1994
39. Jones, M., Santanello, S.A., Falcone, R.E.: Percutaneous endoscopic vs surgical gastrostomy. J.P.E.N. *14*:533, 1990
40. Stiegmann, G., Goff, J., VanWay, C., Perino, L., Pearlman, N., Norton, L.: Operative versus endoscopic gastrostomy: preliminary results of a prospective randomized trial. Am. J. Surg. *155*:88, 1988
41. Apelgren, K.N., Zambos, J.: Is percutaneous gastrostomy better than open gastrostomy? A clinical study in one surgical department. Am. Surg. *55*:596, 1989
42. Edelman, D.S., Arroyo, P.J., Unger, S.W.: Laparoscopic gastrostomy versus percutaneous endoscopic gastrostomy: a comparison. Surg. Endosc. *8*:47, 1994
43. Henderson, J.M., Strodel, W.E., Gilinski, N.H.: Limitations of percutaneous endoscopic jejunostomy. J.P.E.N. *17*:546, 1993

44. Rai, J., Flint, L.M., Ferrara, J.J.: Small bowel necrosis in association with jejunostomy tube feedings. Am. Surg. *62*:1050, 1996
45. Adams, D.B.: Feeding jejunostomy with endoscopic guidance. Surg. Gynecol. Obstet. *172*:239, 1991
46. Bumpers, H.L., Luchette, C.A., Doerr, R.J., Hoover, E.L.: A simple technique for insertion of PEJ via PEG. Surg. Endosc. *8*:121, 1994
47. Gray, R.R., St Louis, E.L., Grosman, H.: Modified catheter for percutaneous gastrojejunostomy. Radiology *173*:276, 1989
48. Gray, R.R., Ho, C.S., Yee, A., Montanera, W., Jones, D.P.: Direct percutaneous jejunostomy. A.J.R. *149*:931, 1987
49. Ramesh, S., Dehn, T.C.: Laparoscopic feeding jejunostomy. Br. J. Surg. *83*:1090, 1996
50. Gui, G.P., Cheruvu, C.V., Fiennes, A.G.: Surgical technique: intracorporeal laparoscopic-guided feeding jejunostomy. Ann. R. Coll. Surg. Engl. *79*:462, 1997
51. Hotokesaka, M., Adams, R.B., Miller, A.D., McCallum, R.W., Schirmer, B.D.: Laparoscopic percutaneous jejunostomy for long-term enteral access. Surg. Endosc. *10*:1008, 1996
52. Murayama, K.M., Johnson, T.J., Thompson, J.S.: Laparoscopic gastrostomy and jejunostomy are safe and effective for obtaining enteral access. Am. J. Surg. *172*:591, 1996
53. Garanowski, L.: Central venous access devices. J. Intraven. Nurs. *16*:167, 1993
54. Fisher, K.L., Leung, A.N.: Radiographic appearance of central venous catheters. A.J.R. *166*:329, 1996
55. Lilienberg, A., Bengtsson, M., Starkhammar, H.: Implantable devices for venous access: nurses' and patients' evaluation of three different port systems. J. Adv. Nurs. *19*:21, 1994
56. Carrera-Villamor, J.M., Reyes Perez, R., Pulido-Duque, J.M., Gomez, E., Pardo, M.D., Argilles Vives, J.M., Eyheremendy, E.P., Maynard Moliner, M.: Percutaneous implant of Hickman catheters and reservoirs: long-term experience. Rev. Clin. Esp. *197*:740, 1997
57. Gullo, S.M.: Implanted ports. Nurs. Clin. North Am. *28*:859, 1993
58. Ross, M.N., Haase, G.M., Poole, M.A., Burrington, J.D., Odom, L.F.: Comparison of totally implanted reservoirs with external catheters as venous access devices in pediatric oncologic patients. Surg. Gynecol. Obstet. *167*:141, 1988
59. Mirro, J., Jr., Rao, B.N., Stokes, D.C., Austin, B.A., Kumar, M., Dahl, G.V., Colten, T.M., Ballas, L., Rafferty, M., Hancock, M.: A prospective study of Hickman/Broviac catheters and implantable ports in pediatric oncology patients. J. Clin. Oncol. *7*:214, 1989
60. Mirro, J., Jr., Rao, B.N., Kumar, M., Rafferty, M., Hancock, M., Austin, B.A., Fairclough, D., Lobe, T.E.: A comparison of placement techniques and complications of externalized catheters and implantable port use in children with cancer. J. Pediatr. Surg. *25*:120, 1990
61. Ingram, J., Weitzman, S., Greenberg, M.L., Parkin, P., Filler, R.: Complications of indwelling venous access lines in the pediatric hematology patient: a prospective comparison of external venous catheters and subcutaneous ports. Am. J. Pediatr. Hematol. Oncol. *13*:130, 1991
62. Mueller, B.U., Skelton, J., Callender, D.P., Marshall, D., Gress, J., Longo, D., Norton, J., Rubin, M., Venzon, D., Pizzo, P.A.: A prospective randomized trial comparing infectious and noninfectious complications of an externalized catheter versus a subcutaneously implanted device in cancer patients. J. Clin. Oncol. *12*:1943, 1992
63. Pegues, D., Axelrod, P., McClarren, C., Eisenberg, B.L., Hoffman, J.P., Ottery, F.D., Keidan, R.D., Boraas, M., Weese, J.: Comparison of infections in Hickman and implanted port catheters in adult solid tumor patients. J. Surg. Oncol. *49*:156, 1992
64. Keung, Y., Watkins, K., Chen, S., Groshen, S., Silberman, H., Douer, D.: Comparative study of infectious complications of different types of chronic central venous access devices. Cancer *73*:2832, 1994
65. Muscedere, G., Bennett, J.D., Lee, T.Y., Mackie, I., Vanderburgh, L.: Complications of radiologically-placed central venous ports and Hickman catheters in patients with AIDS. Can. Assoc. Radiol. J. *49*:84, 1998
66. Shapiro, C.L.: Central venous access catheters. Surg. Oncol. Clin. North Am. *4*:443, 1995
67. McCarthy, M.C., Shives, J.K., Robinson, R.J., Broadie, T.A.: Prospective evaluation of single and triple-lumen catheters in total parenteral nutrition. J.P.E.N. *11*:259, 1987
68. Early, T.F., Gregory, R.T., Wheeler, J.R., Snyder, S.O., Jr., Gayle, R.G.: Increased infection rate in double-lumen versus single-lumen Hickman catheters in cancer patients. South. Med. J. *83*:34, 1990
69. Clark-Christoff, N., Watters, V.A., Sparks, W., Snyder, P., Grant, J.P.: Use of triple-lumen subclavian catheters for administration of total parenteral nutrition. J.P.E.N. *16*:403, 1992
70. Rose, S.G., Pitsch, R.J., Karrer, F.W., Moor, B.J.: Subclavian catheter infections. J.P.E.N. *12*:511, 1988
71. Shulman, R.J., Smith, E.O., Rahman, S., Gardner, P., Reed, T., Mahoney, D.: Single versus double-lumen central venous catheters in pediatric oncology patients. Am. J. Dis. Child. *142*:839, 1988
72. Gil, R.T., Kruse, J.A., Thill-Baharozian, M.C., Carlson, R.W.: Triple vs single-lumen central venous catheters: a prospective study in a critically ill population. Arch. Intern. Med. *149*:1139, 1989
73. Johnson, B.H., Rypins, E.B.: Single lumen vs double-lumen catheters for total parenteral nutrition: a randomized prospective trial. Arch. Surg. *125*:990, 1990
74. Farkas, J.C., Liu, N., Bleriot, J.P., Chevret, S., Goldstein, F.W., Carlet, J.: Single versus triple-lumen central catheter-related sepsis: a prospective randomized study in a critically ill population. Am. J. Med. *93*:277, 1992
75. Babycos, C.R., Barrocas, A., Webb, W.R.: A prospective randomized trial comparing the silver-impregnated collagen cuff with the bedside tunneled subclavian catheter. J.P.E.N. *17*:61, 1993
76. Ciresi, D.L., Albrecht, R.M., Volkers, P.A., Scholten, D.J.: Failure of antiseptic bounding to prevent central venous catheter-related infection and sepsis. Am. Surg. *62*:641, 1996
77. Pemberton, L.B., Ross, V., Cuddy, P., Kramer, H., Fessler, T., McGurk, E.: No difference in catheter sepsis between standard and antiseptic central venous catheters: a prospective randomized trial. Arch. Surg. *131*:986, 1996
78. Heard, S.O., Wagle, M., Vijayakumar, E., McLean, S., Brueggemann, A., Napolitano, L.M., Edwards, L.P., O'Connell, F.M., Puyana, J.C., Doern, G.V.: Influence of triple-lumen central venous catheters coated with clorhexidine and silver sulfadiazine on the incidence of catheter-related bacteremia. Arch. Intern. Med. *12*:81, 1998
79. Tennenberg, S., Lieser, M., McCurdy, B., Boomer, G., Howington, E., Newman, C., Wolf, I.: A prospective randomized trial of an antibiotic and antiseptic-coated central venous catheter in the prevention of catheter-related infections. Arch. Surg. *132*:1348, 1997
80. Kemp, L., Burge, J., Choban, P., Harden, J., Flancbaum, L.: The effect of catheter type and site on infection rates in total parenteral nutrition patients. J.P.E.N. *18*:71, 1994
81. Bennett, J.D., Papadouris, D., Rankin, R.N., McGloughlin, R.F., Kribs, S., Kozak, R.I., Garvin, G., Elliott, J.: Percutaneous inferior vena caval approach for long-term central venous access. J. Vasc. Intervent. Radiol. *8*:851, 1997
82. Chang, M.Y., Morris, J.B.: Long-term central venous access through the ovarian vein. J.P.E.N. *21*:235, 1997
83. Mathur, M.N., Storey, D.W., White, G.H., Ramsey-Stewart, G.: Percutaneous insertion of long-term venous access catheters via the external iliac vein. Aust. N.Z. J. Surg. *63*:858, 1993
84. Murphy, L.M., Lipman, T.O.: Central venous catheter care in parenteral nutrition: a review. J.P.E.N. *11*:190, 1987
85. Curtas, S., Bonaventura, M., Meguid, M.M.: Cannulation of inferior vena cava for long-term central venous access. Surg. Gynecol. Obstet. *168*:121, 1989
86. Chung, D.H., Ziegler, M.M.: Central venous catheter access. Nutrition *14*:119, 1998
87. Kanter, R.K., Zimmerman, J.J., Strauss, R.H., Stoeckel, K.A.: Central venous catheter insertion by femoral vein: safety and effectiveness for the pediatric patient. Pediatrics *77*:842, 1986
88. Purdue, G.F., Hunt, J.L.: Vascular access through the femoral vessels: indications and complications. J. Burn Care Rehabil. *7*:498, 1986
89. Carey, P.C., Mann, D.V., Pearce, S.Z., Windsor, A.C., Pullyblank, A.M., Guillou, P.J., Monson, J.R.: Long-term circulatory access via a peripheral implantable port. Br. J. Surg. *80*:600, 1993
90. Ng, P.K., Ault, M.J., Ellrodt, A.G., Maldonado, L.: Peripherally inserted central catheters in general medicine. Mayo Clin. Proc. *72*:225, 1997
91. Yeung, C.Y., Lee, H.C., Huang, F.Y., Wang, C.S.: Sepsis during total parenteral nutrition: exploration of risk factors and determination of

the effectiveness of peripherally-inserted central venous catheters. Pediatr. Infect. Dis. J. *17*:135, 1998
92. Raad, I., Davis, S., Becker, M., Hohn, D., Houston, D., Umphrey, J., Bodey, G.P.: Low infection rate and long durability of nontunneled Silastic catheters: a safe and cost-effective alternative for long-term venous access. Arch. Intern. Med. *153*:1791, 1993
93. Polak, J.F., Anderson, D., Hagspiel, K., Mungovan, J.: Peripherally inserted central venous catheters: factors affecting patient satisfaction. A.J.R. *170*:1609, 1998
94. Mateu, J., Gil, M.E.: Parenteral nutrition by peripheral route: considering all points. J.P.E.N. *21*:117, 1997
95. Jimenez Jimenez, F.J., Ortiz, C., Jimenez Jimenez, L., Garcia Valdecasas, M.S.: [Hypocaloric peripheral parenteral nutrition in postoperative patients.] Nutr. Hosp. *9*:139, 1994
96. Macfie, J.: Infusion phlebitis and peripheral parenteral nutrition. Nutrition *14*:233, 1998
97. Kuwahara, T., Asanami, S., Tamura, T., Kubo, S.: Dilution is effective in reducing infusion phlebitis in peripheral parenteral nutrition: an experimental study in rabbits. Nutrition *14*:186, 1998
98. Madan, M., Alexander, D.J., McMahon, M.J.: Influence of catheter type on the occurrence of thrombophlebitis. Lancet *339*:101, 1992
99. Jinley, R.J.: Venous reactions related to indwelling plastic cannulae: a prospective clinical trial. Curr. Med. Res. Opin. *3*:607, 1976
100. Nordenstrom, J., Jeppsson, B., Loven, L., Larsson, J.: Peripheral parenteral nutrition: effect of a standardized compounded mixture on infusion phlebitis. Br. J. Surg. *78*:1391, 1991
101. Matsusue, S., Nishimura, S., Koizumi, S., Nakamura, T., Takeda, H.: Preventive effect of simultaneously infused lipid emulsion against thrombophlebitis during postoperative peripheral parenteral nutrition. Surg. Today *25*:667, 1995
102. Khawaja, H.T., Williams, J.D., Weaver, P.C.: Transdermal glyceril trinitrate to allow peripheral total parenteral nutrition: a double blind placebo-controlled feasibility study. J.R. Soc. Med. *84*:69, 1991
103. Williams, N., Wales, S., Irving, M.H.: Prolonged peripheral parenteral nutrition with an ultrafine cannula and low osmolality feed. Br. J. Surg. *83*:114, 1996
104. Hecker, J.F.: Potential for extending survival of peripheral intravenous infusions. B.M.J. *304*:619, 1992