Learning Objectives:

- To select the best venous access for PN administration in considering the advantages and risks of each site;
- To describe the protocols (proper skin preparation, insertion and manipulation of the catheter, administration set, pump, filter, etc) to assure safe administration of PN;
- To consider the type of PN bags to assure adequate administration.

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Key Messages:

- The subclavian vein should be the first choice for inserting a catheter for PN administration;
- Ultrasound-guided vein puncture is strongly recommended for access to all central veins;
- The ideal position of the catheter tip is between the lower third of the superior cava vein and the upper third of the right atrium;
- A peripheral route could be used for a short-term period of PN (with low osmolality admixtures);
- Strict protocols are mandatory for handling of the central venous catheter;
- Chlorhexidine solution is superior to aqueous povidone iodine (PVI) solution for cutaneous antisepsis;
- A pump for regulating the flow is recommended; the use of filters is still debatable;
- The selection of PN bags (hospital-made or commercialized ready-to-use) should be based on the patient’s needs and expected duration of PN.
1. Introduction

Parenteral nutrition (PN) is used to provide nutritional support to subjects who are unable to be orally or enterally fed. Transient intestinal insufficiency is the main indication for short-term PN for hospitalized patients. In some rare cases of life-threatening intestinal failure, long-term PN may be safely perfused at home.

Solutions used in total parenteral nutrition, which provides all nutrients, including carbohydrates, amino acids, electrolytes, minerals and vitamins, are by necessity very hypertonic, ameliorated somewhat by constituent fat emulsions. The osmolality of PN admixtures are three to 8 times the normal serum osmolality. So, their infusion into small vessels or into vessels with low blood flow provokes severe burning and rapid thrombosis of the vein.

The development of total parenteral nutrition has therefore required techniques to gain access to veins with high blood flow, such as the superior vena cava, the right atrium, the inferior vena cava, or a surgically created arterio-venous fistula. However, the development of some new pharmaceutical compounds with a lower osmolality allows the use of a peripheral route for infusing parenteral nutrition, at least for a short-term period.

2. History

The most common vascular access used for PN is the percutaneously placed subclavian vein catheter (Fig. 1). This technique was first introduced in 1952 by Aubaniac, who found that the technique provided rapid access to the central venous system with minimal complications in patients suffering from military injuries (1).

![Fig.1. Subclavian vein catheterization](image)

The use of the subclavian catheter for intravenous nutritional support was initially proposed by Dudrick and colleagues in 1969 (2). Afterwards, others described the use of the internal jugular vein (Fig. 2-3), the external jugular vein, the basilic vein and even the right atrial appendage.
Fig. 2. Internal jugular vein anatomy

Fig. 3. Catheterization of internal jugular vein
Although first described in 1949 by Duffy, the use of an inferior vena caval catheter via the femoral vein has found little clinical application because of the high risk of infection and thrombosis (3) (Fig. 4).

Fig.4. Catheterization of the femoral vein

3. Basic principles for central venous catheter (CVC) placement

3.1. Proper patient preparation

Before the placement of a central venous catheter (CVC) for administering PN, the nurse and the physician should adequately explain to the patient the reason for the catheter
placement and the technique to be used. As for any other procedure, information given to the patient may lower anxiety, fears or misconceptions. When properly informed, most patients will not require sedation but only local anaesthetic infiltration. The patient should be informed to expect some discomfort, even if local anaesthesia is performed. The placement of a CVC is generally performed with the patient in his bed, in a supine position. Generally, the head is turned away from the cannulation site in order to facilitate the vein cannulation. With regard to the hospital facilities, the placement of a CVC is performed either in the patient’s room or – probably better – in a dedicated operating room.

3.2. Proper timing of catheterization

Placement of a central venous catheter for PN should always be done on an elective basis in a well informed patient, in a proper environment and by an experienced physician in order to limit the risk of complications (Table 1).

Table 1. Complications in relation to insertion of CVC

<table>
<thead>
<tr>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local infection or haematoma</td>
</tr>
<tr>
<td>Bleeding from the subcutaneous tunnel and the puncture site</td>
</tr>
<tr>
<td>Arterial puncture</td>
</tr>
<tr>
<td>Haemothorax</td>
</tr>
<tr>
<td>Pneumothorax</td>
</tr>
<tr>
<td>Haemopericardium and cardia tamponnade</td>
</tr>
<tr>
<td>Cardiac arrythmias</td>
</tr>
<tr>
<td>Misplacement and migration of the catheter</td>
</tr>
<tr>
<td>Venous embolism</td>
</tr>
<tr>
<td>Air embolism</td>
</tr>
</tbody>
</table>

3.3. Proper skin preparation

The area of proposed cannulation is first shaved carefully, if needed. The physician must cleanse the hands with antiseptic soap. The standard of care for catheter-related blood stream infection prevention must include the use of sterile gloves, a long-sleeved sterile gown, a mask, a gap and a large sterile drape during catheter insertion (5) (Fig. 5).

Fig. 5. Hands’ cleansing
A wide area around the proposed cannulation site should be thoroughly cleaned with an antiseptic soap (Fig. 6).

Fig. 6. Skin disinfection

Chlorhexidine solution is superior to aqueous povidone iodine (PVI) solution for cutaneous antisepsis (6). Alcohol rubs used in preparation for surgery by the scrub team are as effective as aqueous scrubbing for preventing infection (7). Recent data suggest that octenidim in alcoholic solution is a better option than alcohol alone for prevention of CVC-associated infections (8,9). The American Pediatric Surgical Association also stated that chlorhexidine skin prep and chlorhexidine-impregnated dressing can decrease CVC colonization and bloodstream infection. Chlorhexidine-impregnated sponges for central venous catheters save money by preventing major catheter-related infections, even in intensive care units with low baseline major catheter-related infection levels (10,11). A sterile draping should follow. The number of people in the room should be limited to the assisting nurse to avoid airborne contamination, and all those present must wear masks.

3.4 Availability of a proper equipment and supplies

It seems cost-effective to develop a catheter insertion tray, that consists of bowls, clamps, syringes, and sponges. In addition to the tray materials, a cart containing the various preparation solutions, gowns, gloves, masks and catheters greatly assists the catherization (Fig. 7).
4. Central venous cannulation

Selection of the insertion site should be based on both the case and the risks of the procedure. The risks include infection, thrombosis and mechanical complications. Subclavian access is preferred for infection control purposes, although other factors (potential mechanical complication, thrombosis and operator experience) should be considered (12,13).

Landmarks used in a central vein catheterization should be based on anatomic relationships (4) (Fig. 8).

Fig.8. Landmarks for central vein catheterization
The subclavian vein can be approached via a supraclavicular or infraclavicular route. After adequate patient preparation, a small wheal of local anaesthetic should be placed at the proposed puncture site (Fig. 9).

Fig. 9. Local anaesthesia

The needle is then advanced through the anaesthetized skin toward the target area (Fig. 10-11).

Fig. 10. Needle insertion
Fig. 11. Vein cannulation

As the needle is advanced, intermittent aspiration on the syringe confirms passage into the vein by a rapid rush of blood into the barrel of the syringe. Once the needle has been advanced into the vein, a guidewire is advanced through the needle, and the needle is subsequently removed (Fig. 12).

Fig. 12. Wire insertion

Care must be taken during this procedure to avoid aspiration. Failure of the guidewire to advance easily usually means that the needle is no longer within the vein or that it is against the vein's wall. Once the guidewire is in place, the catheter is passed over the wire, and the wire is removed. Following the presumed proper placement of the central venous catheter, chest X-ray is necessary to document the position of the catheter as well as the rule out the presence of a pneumothorax. In practice, a 5% dextrose solution should be connected until the X-ray is obtained. After proper catheter placement, a sterile dressing should be applied. Utilization of the internal and external jugular veins for CVCs is maybe less recommended than the subclavian veins but quite effective. Because of the higher positioning of the puncture site on the neck, difficulties in maintaining a sterile dressing limit their long-term use (Fig. 13). In addition, the small size of the external jugular vein can result in thrombosis of the system.
There is a higher risk of thrombophlebitis in using the basilic vein. The catheters do limit the mobility of the arm and are somewhat less comfortable. The use of the femoral vein should be reserved for patients with thrombosis of the upper central veins. The use of femoral catheters is associated with a higher rate of thrombosis and should probably be restricted to thin patients, in whom the rates of mechanical complications (i.e. pneumothorax and haemorrhage) are unacceptably high with other routes (14). These patients must be monitored carefully for the development of phlebitis and particularly for possible pulmonary embolism. On rare occasions, when superior vena caval thrombosis is present and the risks of using the inferior vena cava are too high, catheters have been placed via a small anterior thoracotomy through the right atrial appendage into the right atrium (15).

The advantages and disadvantages for each anatomic site are listed in Table 2.

### Table 2. Central venous catheter for parenteral nutrition

<table>
<thead>
<tr>
<th></th>
<th>Subclavian</th>
<th>Internal jugular</th>
<th>Brachial</th>
<th>Axillar</th>
<th>Femoral</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk of complication at placement</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Risk of septic complication</strong></td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Risk of thrombosis</strong></td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Ranking for first choice</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Ultrasound-aided insertion and catherization by a clinical expert reduce the risk of procedure-related complications (16,17,18).

**4.1. Position of the distal tip**

Positioning the distal tip of the catheter at the junction of the superior vena cava and the right atrium is recommended (Fig. 14).
Fig. 14. Right positioning of the distal tip of CVC

Radiography or fluoroscopy are required to confirm the position of the distal tip and any procedure-related complications, such as pneumothorax, prior to commencing PN (Fig. 15) (19). It appears that the single most important factor in catheter longevity that is influenced by the surgeon on the anaesthesiologist is tip location at the superior vena cava, right atrial junction (20).
Fig. 15. a. Left internal jugular  
   b. Subclavian vein with subcutaneous air infiltration  
   c. Port

4.2. Replacement of the catheter

Repeated catheterization may be unavoidable but increases the risk of catheter infection. Given this fact and the results of randomized studies, CVCs that are functioning in patients with no evidence of local or systemic complications should not be replaced routinely (21).

5. Central venous catheters

5.1. Material used for venous catheters

Plastics used for venous catheters should be biologically compatible, physically and chemically stable and well tolerated by the organic tissues and mechanisms of defence. The characteristics of the 3 types of plastic used for venous catheters are described in Table 3 (22).
Table 3. Types of plastic venous catheters

<table>
<thead>
<tr>
<th>Material</th>
<th>Chemical inertia</th>
<th>Bio-compatibility</th>
<th>Hemo-compatibility</th>
<th>Mechanical performance</th>
<th>Bio-stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teflon®</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Silicone</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
</tbody>
</table>

5.2. Types of catheter

5.2.1. Catheters for peripheral veins

Conditional on the use of commercialized low osmolality all-in-one mixtures, the peripheral route may be used for the administration of parenteral nutrition, at least in the short-term (23) (Fig. 16).

Fig.16. Peripheral access

In adults, catheters with a calibre from 18 to 22 Gauge are commonly used. Catheters, with a length of less than 80 mm, have an universal luer lock connection. It is recommenced to use first the peripheral veins which are distally located on the hands or arms. Veins of the feet or legs should be avoided due to the high risk of septic and thrombotic complications.

5.2.2. Catheters for central veins

The catheters that are most used are composed of polyurethane. The catheter’s length varies from 60 cm for a brachial insertion to 13 cm for a subclavian or internal jugular vein. The appropriate length of CVC inserted through the right internal jugular vein or right subclavian vein can be estimated by the calculated measurement of adding half the length of the right clavicle and the vertical length between the sternal head of the right clavicle and the carina (24).

There are catheters with a single, double or triple lumens. For the latter, the calibre of 2 lumen catheters is typically 18 Gauge, and 14 Gauge for the triple lumen ones. The efficacy of antiseptic impregnated catheters (chlorhexidine, silver-sulfadiazine) in lowering the risk of bloodstream infection is still a question of debate (25).
For ICU patients requiring the administration of PN, it is highly recommended to use a double lumen catheter in order to avoid mixing of parenteral admixtures and other drugs (Fig. 17).

Fig. 17. Double lumen catheter

Indeed, except for a very few drugs, mixing with drugs may provoke a physical or chemical instability of the parenteral nutrition.

5.2.3. Long-term parenteral nutrition

For patients who require long-term PN, there are various additional vascular access devices (see Home Parenteral Nutrition for details). In some cases, the vascular device could also be used for chemotherapy.

5.2.3.1. Skin-tunneled central venous catheter

As was proposed by Broviac et al and Hickman et al, the superior vena cava is catheterized with a tunneled, silicone rubber catheter. Fixation is achieved through the ingress of adhesions from the subcutaneous tissues into a felt cuff, which is attached to the catheter and positioned within the skin tunnel (Fig. 18).
5.2.3.2. Subcutaneously inserted central venous ports

The catheter ends in a lightweight, subcutaneous port, incorporating a reservoir chamber covered by a thick silicone septum. Access to the venous system is achieved by inserting a non-coring needle (hypodermic needles damage the silicone) through the skin and septum into the reservoir (Fig. 19). Central venous double-lumen port systems as a therapeutic option in patients requiring chemotherapy and parenteral nutrition can increase safety during those simultaneous applications, while offering improved patient comfort (26).
5.2.3.3. Peripherally inserted central venous catheters (PICC-lines)

PICC lines are acceptable only for relatively short periods of HPN, due to their limitations on physical activity and self-management (27) (Fig. 20).

![Fig.20. PICC-line](image)

5.2.3.4. Closed distal tip

Groshong® catheters, which have a closed, rounded distal tip incorporating a three-position valve, are another option. The valve is closed when the catheter is not in use, but open outward during infusions and inward if blood is withdrawn. As reflux of blood into the catheter tip is avoided, saline – rather than heparin flushes – are recommended in order to maintain patency between infusions. Groshong® catheters are available as a cuffed, tunnelled catheter, an implantable port or as a peripherally inserted central catheter.

6. Handling connections of nutritional bags (Fig. 21-32)

![Fig. 21](image)

Fig. 21 Position of the patient in his bed in a recumbent position; the patient and the nurse should wear a mask.
Fig. 22 Wash hands with antiseptic hand wash. Prepare the working surface with physical and bacteriological cleaning.

Fig. 23. Open a large non-sterile drape and dress the patient's chest.
Fig.24. Mix the bag and hang it up. Wash hands with antiseptic solution again.

Fig.25. Open the packaging, add the sterile material as well as gauze soaked with disinfectant.
**Fig. 26.** Open and place the sterile drape on top of the other one. Place the distal end of the administration set on the sterile drape and flush the system. Wash hands with antiseptic hand wash again.

**Fig. 27.** Disinfect the distal tip of the catheter with a gauze soaked with disinfectant, close the set administration and clamp the catheter.
**Fig. 28.** Put on sterile gloves.

**Fig. 29.** Disconnect the administration set; disinfect the catheter hub. Connect the new administration set.
**Fig.30.** Protect the connector and the hub with a gauze. Open the catheter.

**Fig.31.** Protect the connector and the hub with a gauze. Open the catheter.
Adjust the flow rate with the pump or the manual regulating device.

Semipermeable transparent dressings, which are widely used, allow continuous observation of the skin insertion site and reduce the risk of extrinsic colonization (Fig. 32). A gauze dressing is preferred if blood is oozing from the catheter insertion site. Catheter dressings should be changed immediately if they become damp, loosened, or soiled.

Fig. 32. Semipermeable transparent dressings
The optimal frequency of routine of CVC dressing changes is unknown. The interval between scheduled changes can be safely increased to 7 days in the ICU, provided soiled and loosened dressings are changed immediately (27,28). Obviously, this protocol may be adapted to local recommendations. Employing a parenteral nutrition surveillance nurse has been shown to be cost-effective through the prevention of catheter-related bloodstream infections (29).

7. Administration sets

Administration sets that are used for the administration of parenteral nutrition are similar to those used for intravenous perfusion. It is recommended to replace the administration set every day in care of lipid-based PN and every 2-3 days if the bags do not contain lipid emulsions (30).

The use of a multi-lumen catheter allows one lumen to be reserved for parenteral nutrition and the other(s) for fluids, electrolytes and intravenous medications (31). It is recommended that 1.2-micron filters are used because they avoid not only precipitates but also the coalescence of oil droplets and other particles in the lungs (32). Filters incorporated in the administration set are available, that provide the advantage of diminishing line manipulation (especially in the case of Home Parenteral Nutrition). The use of a pump for regulating the flow is also recommended.

8. Preparation and choice of parenteral solutions

This aspect of the administration of PN is developed in another chapter. However, clinicians should be aware that the main problems in PN preparation are emulsion stability and calcium phosphate precipitation. Some authors have recommended the separate administration of lipids. But, calcium phosphate precipitation can be avoided by using organic phosphates and most PN emulsions are stable if we follow preparation protocols.

When lipids are administered separately, two different lines (or lumen) should be used to avoid stability problems.

In practice, the use of separated bottles is an arduous procedures requiring multiple manipulations, has a high risk of microbial contamination and is poorly adapted to the patient's requirements (Fig. 33). A recent study showed that compound parenteral nutrition was associated with a higher incidence of bloodstream infection (33).

![Fig.33. Separated bottles](image-url)
"All-in-one" PN mixtures have some advantages:
1) they need less line manipulation;
2) they are less costly;
3) they need only one administration pump;
4) micro-organisms reproduce with more difficulty than in lipids alone.

Besides the use of separated bottles – which is not recommended – the physicians have two options: either hospital-made PN bags or ready-to-use PN.

For hospital made mixtures, the composition and amounts of nutrients have been determined by the local pharmacist and physician. The bags are prepared in the local Hospital Pharmacy, following strict protocols (Fig. 34 a,b). In most cases, hospital made mixtures are compounded in a one-chamber bag; they can be binary or ternary (lipid based).

Fig.34. a,b Hospital made bags

Vitamins and trace elements are supplemented by the pharmacist and the electrolyte content may be adapted to each individual. The bags are ready to use; they should be stored in a fridge and used within 5 to 7 days.

The guarantee of aseptic technique is based on the following:
1) Strict follow-up of the PN preparation protocol.
2) The use of laminar flow cabins in a specific clean area.
3) The quality of solutions and emulsions.
4) The validation of the elaboration process.
5) The microbiological controls.
6) The training of personnel.

Concerning the commercialized "ready-to-use" mixtures, the composition and amount of nutrients have been determined by the various commercial companies that ensure both emulsion stability and the absence of compatibility problem (Fig. 35, 36, 37).

**Fig. 35.** Fresenius "ready to use" compounding

**Fig. 36.** Baxter "ready to use" compounding
There are multi-chamber (2 or 3) bags made by pharmaceutical companies with pre-defined compositions. While most of them should be infused into a central vein, there are ready-to-use bags that have been designed for peripheral administration (34). Trace elements and vitamins should be added either by the pharmacist or by the nurse on the ward before administration. The multichamber system offers a long shelf life of 12 months at room temperature. The choice between the "ready-to-use" and the hospital-made all-in-one bags should be based on the algorithm described on Table 4.

**Table 4. Algorithm for selecting the nutritional bags**

<table>
<thead>
<tr>
<th>Parenteral nutrition for complement and/or short duration</th>
<th>Parenteral nutrition in case of severe underlying diseases and long-term</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓ Standard nutritional requirements</td>
<td>↓ Specific nutritional requirements</td>
</tr>
<tr>
<td>↓ &quot;Ready-to-use&quot; 2 or 3 commercialized chambers bags</td>
<td>All-in-one bags prepared by the local pharmacist</td>
</tr>
<tr>
<td>↓ Vitamins and trace elements to be added</td>
<td>Tailored prescription which is adapted to each individual</td>
</tr>
<tr>
<td>↓ Addition in electrolyte could be needed</td>
<td></td>
</tr>
</tbody>
</table>

**9. Summary**

Administration of parenteral nutrition was initiated in the late sixties using central venous catheters. Indeed, due to the high osmolality of parenteral nutrition, nutritional admixtures must normally be infused into large veins in order to avoid thrombophlebitis and thrombosis.
The subclavian vein seems to be the first choice but other sites such as the internal jugular vein, the basilic and axillary and – in rare cases – the femoral vein can be also used. Recent development in low osmolality "all-in-one" solutions allows the administration of PN in peripheral veins, at least in the short term.

The placement of central venous catheter should be done by an experienced physician, in a well informed patient and in an appropriate environment. Ultrasound-guided vein puncture is strongly recommended for access to all central veins. The ideal position of the catheter tip is between the lower third of the superior cava vein and the upper third of the right atrium. Chlorhexidine solution is superior to aqueous povidone iodine solution for cutaneous antisepsis.

Handling of central venous catheters should follow strict protocols and be performed only by trained personnel.

10. References

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