

Intensive Care Nursery House Staff Manual

Intravascular Catheters

ARTERIAL CATHETERS: Most infants admitted to the ICN will need an arterial catheter for measurement of blood pressure, pH and blood gas tensions. Usually, an umbilical arterial catheter (UAC) is used. Peripheral arterial catheters are indicated when:

- Catheterization of umbilical artery was unsuccessful.
- It is desirable to measure pre-ductal PaO₂ (*i.e.*, from the right radial a.)
- The UAC has been in place several days or was removed due to thrombus formation.
- The infant is too old to catheterize an umbilical artery.

UMBILICAL ARTERIAL CATHETERS have the following advantages:

- Rapid and easy insertion
- Accurate measurement of arterial blood pressure
- Useful for administration of fluids, glucose and medications as well as blood sampling

1. Anatomy: The umbilical arteries are extensions of the internal iliac (hypogastric) arteries and extend from the pelvis to umbilicus in the anterior abdominal wall deep to the rectus muscle and fascia (Figure 1).

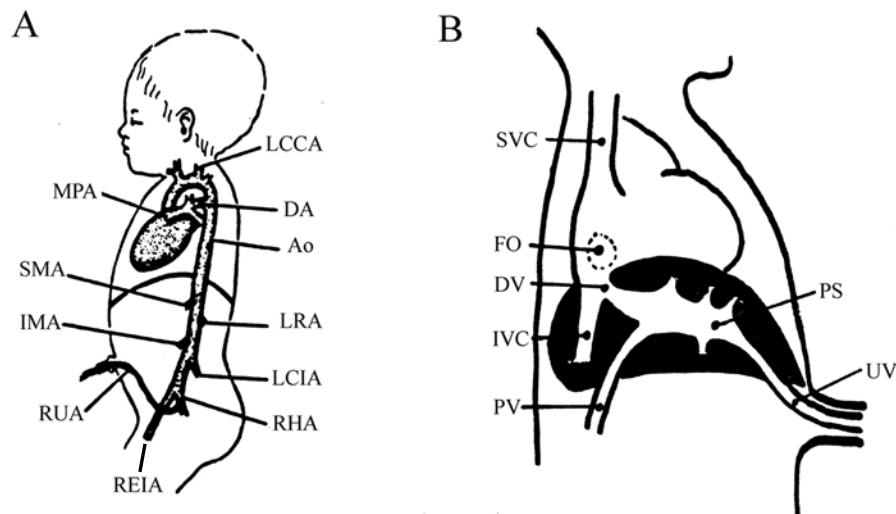


Figure 1A. Diagram of neonatal arterial system including umbilical artery. (Ao, aorta; DA, ductus arteriosus; IMA, inferior mesenteric a.; LCCA, left common carotid a.; LCIA, left common iliac a.; LRA, left renal a.; MPA, main pulmonary a.; REIA, right external iliac a.; RHA, right hypogastric a.; RUA, right umbilical a.)

Figure 1B. Diagram of the umbilical venous system in a newborn infant. (DV, ductus venosus; FO, foramen ovale; IVC, inferior vena cava; PS, portal sinus; PV, portal vein; SVC, superior vena cava; UV, umbilical v.)

B. Insertion of UAC:

1. Preparation. Use UAC Insertion tray and appropriate sterile technique including cap, mask and gloves. Restrain the infant's limbs. For **infants >1500g, use a 5 Fr catheter**; for **those ≤1500g, use a 3.5 Fr catheter**. Attach a stopcock to the catheter and fill the system with sterile heparinized flush solution (usually 0.9% NaCl).

Cleanse umbilical cord and adjacent abdomen with iodine solution. Drape the area so that only the umbilical cord is exposed. Place a cord tie around base of the umbilical cord and tie loosely. Cut the cord about **0.5 cm above the skin line**. If bleeding occurs, tighten the tie.

2. Insertion of catheter. Hold cord stump gently upright. The umbilical vein is the single large, thin-walled vessel. The two arteries are smaller, thick-walled, and often tightly constricted. Gently insert the closed tips of the thin curved forceps into the lumen of an artery; allow the spring of the forceps to spread the forceps tips apart to dilate the artery (In extremely LBW infants, it may be necessary to insert only one tip of the forceps to begin the dilatation). Repeat the process several times until the lumen is well dilated and the forceps can be inserted into the lumen up to the bend in the forceps; this is exceedingly important. **The most common cause of failure to catheterize an umbilical artery is inadequate dilatation of the artery.**

After the artery is well dilated, insert catheter tip into the lumen and advance the catheter while directing it towards the pelvis. The catheter may encounter obstruction at either the level of the abdominal wall or about 5 cm farther, approximately the level of the bladder. The obstruction can usually be overcome by **gentle, steady pressure for 30-60 sec**. Avoid excessive pressure or repeated probing of the artery, as these may cause arterial perforation. If the obstruction persists, leave the catheter in place and insert a catheter in the other artery; in most cases, you will be able to successfully catheterize one of the arteries. When the catheter has passed the point of obstruction, advance it the appropriate distance for the infant's size (Table 1). Then, obtain blood sample for hematocrit, pH and blood gas tensions. Flush the catheter with heparinized saline and use care to avoid infusing bubbles. Measure arterial blood pressure. Then secure the catheter.

Table 1. Guide for distance to insert an umbilical arterial catheter.

<u>Birth Weight (g)</u>	<u>Distance to insert umbilical arterial catheter (cm)*</u>
1,000	7
1,500	8
2,000	9
2,500	10

*Note that this guide cannot be used for umbilical venous catheters.

3. Securing the catheter: Use a round (non-cutting) needle with 4-0 silk, place one suture through the wall of the cord and tie a firm knot. Wrap each end of the suture around the catheter only one time and tie the catheter tightly using a surgeon's knot; tie

firmly but do not occlude the catheter lumen. Be sure catheter cannot slip through the suture. Apply antibiotic ointment to umbilicus, cover with a dry 2x2 dressing and secure dressing and catheter with tape.

4. **Location of catheter tip.** Always verify location of the UAC tip radiographically; **it should be in the abdominal aorta below the 3rd lumbar vertebra (L-3)** and above the aortic bifurcation (usually, bottom of L-4). This will ensure that the tip is below the origin of the inferior mesenteric and renal arteries but still in an area of relatively high blood flow. If the UAC is advanced farther into the aorta and into the thorax, the tip will almost always pass through the ductus arteriosus into the pulmonary artery. This will lead to errors in treatment, because PaO₂ and blood pressure in the pulmonary artery are almost always lower than in the aorta. After completing the catheterization, examine the infant's legs for evidence of decreased femoral arterial blood flow (blanching, mottling, decreased or absent femoral pulse). **If femoral flow is decreased, remove the catheter.**
5. **Catheter maintenance.** Maintain a constant infusion of heparinized fluid through the UAC. Heparin concentration should be 1 unit/mL. Examine the legs daily and remove UAC if there is evidence of decreased femoral blood flow. Also, **remove the UAC if there is damping of the arterial wave form** (See below under Blood Pressure).

C. **Complications of umbilical arterial catheters** are listed below and can cause serious, and sometimes fatal, consequences:

- Ischemia** due to obstruction of blood flow to the legs (see above). When UAC tip is above L-3, there may be occlusion of the inferior mesenteric a. leading to bowel ischemia resulting in necrotizing enterocolitis (NEC). **Do not feed an infant with a UAC.** If abdominal distension or other signs of NEC occur, remove the UAC.
- Thrombosis**, the most common complication of a UAC, may cause damping of the arterial tracing, NEC, renal insufficiency, hypertension (renovascular or secondary to aortic obstruction) or decreased blood flow to the legs. If there are signs of thrombosis, remove the UAC.
- Emboli** occur from small bubbles inadvertently infused into the UAC (*e.g.*, with flushing) or particulate matter from a thrombus on the UAC. **If signs of emboli occur, remove UAC.** Because packed RBCs infused into a UAC have caused infarcts of the spinal cord with resultant paralysis, **do not give packed RBCs through a UAC.**
- Vasospasm:** If the leg blanches, warm the other leg to induce reflex vasodilatation. If improvement does not occur, remove the UAC.
- Hemorrhage** will occur if UAC is accidentally disconnected from stopcock or tubing.
- Vascular perforation** may occur if excessive pressure is used to insert the UAC. Massive intra-abdominal hemorrhage may result.
- Hypoglycemia** can occur if the UAC tip is above the recommended site. The infusion of glucose may stream into the pancreatic a. via the celiac axis, causing hyperinsulinemia and resultant hypoglycemia.
- Infection** is rare with arterial catheters and can usually be prevented by keeping the cord covered with antibiotic ointment and a dry dressing.

PERIPHERAL ARTERIAL CATHETERS are useful in infants in whom UACs cannot be used. Peripheral arterial catheters can often be used for several days; complications have been minor and infrequent. The most commonly used site is the radial a.; the ulnar, dorsalis pedis, posterior tibial and, rarely, the axillary arteries can also be cannulated. Do not use temporal arteries because of possible CNS damage from retrograde emboli. Do not use brachial artery because of poor collateral circulation and risk of ischemia to hand and forearm.

A. Radial Artery Catheterization:

1. Technique.

- (a) Before cannulating or doing a single arterial puncture on a radial a., ensure that the ulnar a. is present by **palpation or by the Allen Test**. To perform the Allen Test, compress both the radial and ulnar arteries. Then, compress the hand to drain blood from the hand. Carefully release the ulnar artery while still compressing the radial. The hand should flush as blood flows through the ulnar artery to the hand. **If the ulnar artery cannot be palpated and the Allen Test is negative, do not use the radial artery in that arm as ischemia of the hand may result.**
- (b) Extend the wrist to about 45° over a gauze pad; secure the hand and arm to a board. Apply tape so that the tips of all 5 fingers are visible. Cleanse the wrist with iodine preparation and wipe with alcohol.
- (c) Palpate the point of maximal pulsation of the radial a. over the distal radius. Insert a #22 catheter (Angiocath™ or similar device) at an angle of 30° to 45° with the skin; use a #24 for very small infants. Advance the needle tip so that it enters the artery.
- (d) When blood return is seen, advance the catheter over the needle into the artery and withdraw the needle.
- (e) If the catheter cannot be advanced, it is not in the arterial lumen. Remove the catheter and apply firm pressure over the artery for several minutes to prevent formation of a hematoma. If a hematoma does form, it will probably not be possible to catheterize that artery.
- (f) After advancing the catheter, attach it to a T-connector filled with heparinized saline for fluid infusion and measurement of blood pressure.
- (g) Carefully secure the catheter to the skin with tape. Examine the tips of all fingers. If blood flow is inadequate, loosen the tape. If no improvement, remove the catheter.

2. Complications of Radial Arterial Catheters include:

- Hemorrhage
- Ischemia of hand
- Retrograde emboli to CNS (if catheter is vigorously flushed)

B. Catheterization of Other Peripheral Arteries. Technique is similar to that used for the radial a. Before cannulating a peripheral artery, be sure you are familiar with the anatomy, including adjacent nerves and alternate routes of blood supply. Do not attempt to cannulate an axillary a. without discussion with Neonatology Fellow or Attending.

C. Fluid Infusion in Peripheral Arteries. In most cases, use 0.9% or 0.45% NaCl. In some cases, 5% glucose can be used in a peripheral artery, but it must be infused at slow rate (*i.e.*, 0.5 to 1.0 mL/h). To prevent vasospasm, lidocaine can be added to the infusion fluid at a concentration of 40 mcg/mL.

VENOUS CATHETERS

UMBILICAL VENOUS CATHETERS: In most circumstances, arterial catheters are safer and more useful than venous catheters. However, in some cases, an umbilical venous catheter (UVC) is desirable (*e.g.*, for exchange transfusion, measurement of central venous pressure).

A. Insertion of UVC: Preparations are similar to those for UAC. The vein is the large, thin-walled vessel in the cord.

- Remove any visible clots in vein with forceps.
- Connect catheter to pressure transducer, before inserting it into the vein.
- Insert catheter using only gentle pressure.
- Never open UVC to atmospheric pressure as this may result in air embolism.
- While continuously measuring pressure, insert catheter into umbilical vein.

B. Location of UVC Tip. Figure 1B shows the relevant anatomy. Note the several possible locations for the UVC tip, including umbilical vein, portal vein, portal sinus, right atrium, left atrium, left ventricle, pulmonary vein and SVC (rare).

1. The preferred location is beyond the ductus venosus in IVC or low right atrium.
2. Placement of UVC tip in the portal system is undesirable for the following reasons:
 - Portal venous pressure is higher than central venous pressure, but by a variable amount and thus gives no useful information about the cardiovascular system.
 - Infusion of hypertonic solutions (*e.g.*, 10% glucose, NaHCO₃) into the portal system may thrombose the portal vein.
 - Exchange transfusion with the UVC tip in the portal system may cause necrotizing enterocolitis.
3. If the UVC tip is advanced farther into the right atrium, it almost always passes through the foramen ovale into left atrium. If advanced farther, the UVC tip will enter either the left ventricle or a pulmonary vein. **Because of the risk of systemic emboli, do not allow the UVC tip to remain in the left side of the heart.**
4. It is very unusual for a UVC to advance up into the SVC and into a jugular vein.

C. Placement of UVC. The location of the UVC tip cannot be determined by the distance the catheter has been inserted. It must be localized using pressure measurements, measurements of PO₂, and by radiograph:

1. Advance UVC while continuously measuring pressure. As the tip passes through the ductus venosus, the pressure will decrease and the wave form will resemble an atrial pressure tracing (See Figure 2). If you are unsure if the tip is in the thorax stimulate the infant to take a deep inspiration or cry. If the UVC tip is in the thorax, there will be a negative pressure during spontaneous inspiration (Figure 2A). Note that the pressure never goes below atmospheric when the UVC tip is in the portal system (Figure 2B).
2. When the UVC tip has entered the thorax, take a blood sample to measure PO₂; If PO₂ is >50 mmHG, it is likely that the UVC tip is in left atrium, pulmonary vein or left ventricle. If it has been advanced into LV, a ventricular pressure wave will be seen. Withdraw UVC until tip is in right atrium (Blood will appear less pink and pressure tracing will have a dominant “a” wave; see below).

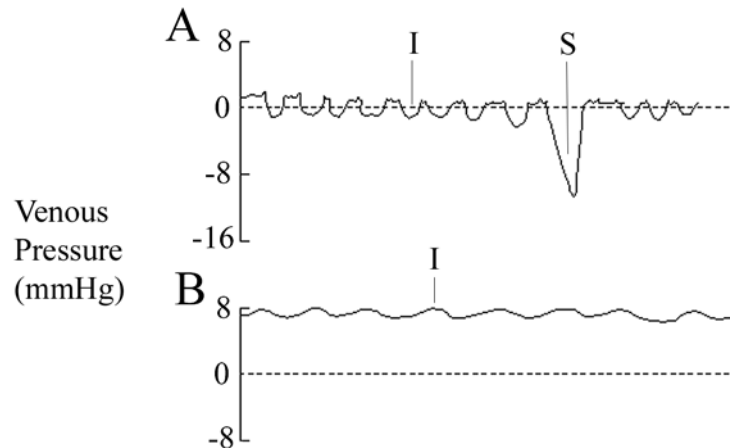


Figure 2. Venous pressures measured through an umbilical venous catheter with tip in the right atrium (A) and in the portal sinus (B). A. With the catheter tip in the right atrium, there are negative pressure deflections (I) during spontaneous inspiration. When the infant takes a deep inspiration or sigh (S), the pressure goes well below atmospheric pressure to about 10 mmHg. B. With the catheter tip below the diaphragm in the portal venous system, the mean pressure is higher than central venous pressure, the pressure goes slightly positive during inspiration (I) and never goes below zero (atmospheric pressure).

3. When catheter has been localized to right atrium by measurements of pressure and PO_2 , secure catheter and obtain a chest radiograph to confirm the position.

D. Complications of umbilical venous catheters include:

-Infection

-Hemorrhage is unusual because of the low pressure in the umbilical venous system.

-Air embolism is a potentially catastrophic event and may occur if bubbles are infused or if the catheter system is opened to the atmosphere when the infant makes a strong inspiratory effort thus decreasing intrathoracic pressure below atmospheric. With the UVC tip in right atrium near the foramen ovale (or in left atrium), emboli will cross the foramen and be distributed in the systemic arterial circulation. Because both the coronary and cerebral circulations have high flows, it is likely that emboli will be distributed there.

-Portal venous thrombosis, especially if hypertonic fluids are infused with the UVC tip in the portal circulation.

-Necrotizing enterocolitis may occur from obstruction of portal venous flow if the tip of the UVC is in the portal circulation during exchange transfusion.

SURGICALLY INSERTED VENOUS CATHETERS: Other central venous catheters (e.g., subclavian, internal or external jugular) are usually inserted for parenteral alimentation. In most cases, these are inserted by a Pediatric or Cardiothoracic surgeon. Catheters used for intravenous alimentation should not be used for routine blood sampling but can be used for measurement of central venous pressure.

PERIPHERALLY INSERTED CENTRAL CATHETERS (PICC) provide extended vascular access. They are very small silicone or polyurethane radiopaque catheters inserted into a peripheral vein via a needle or sheath introducer and advanced to a central location. These are not adequate for measurement of central venous pressure because they are soft and have a high resistance to flow.

1. Patient selection: Infants with the following needs are candidates for PICC placement:

- Predicted need for 5 to 7 d of continuous IV infusion
- Greater than 7 d of IV antibiotics

Early placement, within 24 to 72 h after birth, is preferred, particularly in preterm infants. With known or suspected sepsis, defer PICC placement until the infant has received at least 24 h of IV antibiotic therapy.

2. Insertion procedure:

(a) Preparation: Use prepackaged percutaneous catheter tray. Wash hands and clean work surface with Cavicide™ or alcohol. Ensure supportive care as needed (analgesia, oxygen, assisted ventilation).

(b) Select appropriate site:

- Use lower extremities as 1st choice, right arm next and left arm last. A PICC can also be inserted centrally from a scalp vein.
- Medial antecubital v. is usually easier than cephalic v. to thread to central location
- If using upper extremity, turn patient's head toward selected extremity
- As a general rule, use only one extremity per insertion attempt
- Restrain infant appropriately
- Measure distance for catheter insertion:
 - Upper extremity: measure from entry site to head of right clavicle, then down to 3rd intercostal space.
 - Lower extremity: measure from entry site to the xiphoid process of sternum.
 - Scalp: measure from entry site to head of right clavicle, then down to 3rd intercostal space and add 3 cm.

(c) Insertion technique:

- Open tray, don mask and cap, scrub, and put on sterile gown and gloves. Rinse gloves with sterile water or use powder-free gloves. Prep and drape patient.
- Prepare catheter and needle; measure silastic catheter. Flush with heparinized sterile normal saline. The silicone catheters may be trimmed. Document final length of catheter in procedure note.
- Place catheter and introducer needle, gauze and forceps in sterile work area. **Always use forceps to handle catheter.** Apply sterile tourniquet.
- Insert introducer needle at 30-degree angle into desired vessel, advancing slowly until flashback of blood is evident.
- After flashback is seen:
 - Peel-Away Technique: After flashback, reduce the angle and advance introducer sheath to ensure that the introducer tip is within the vein. **Never reinsert the needle into the introducer sheath if the venipuncture is unsuccessful. This could result in a sheared or severed introducer sheath.** Withdraw the needle from the sheath, supporting the introducer sheath to

avoid displacement. Apply digital pressure on the vessel above the insertion site to minimize bleeding.

-Breakaway Technique: Ensure stability of introducer needle while advancing catheter into vein.

- Insert catheter into sheath/introducer needle and advance slowly to desired depth using forceps. Loosen tourniquet after catheter is advanced beyond tip of introducer. Flush intermittently to facilitate catheter advancement. **Do not withdraw catheter while needle is in the vein, as this may shear off catheter.** During insertion, observe ECG for dysrhythmia or bradycardia.
- Once catheter has been advanced to proper position, withdraw sheath/introducer needle while maintaining pressure on vein just beyond the needle tip to prevent inadvertent withdrawal of the catheter. Continue to apply pressure over the needle insertion site after the needle/sheath has been removed, as bleeding is common and often lasts for a few minutes.
- After withdrawing needle or sheath:
 - Peel-Away technique: Split the introducer sheath and peel it away from the catheter, using care to maintain catheter position.
 - Breakaway technique: With the wings of needle facing downward, grasp each wing between thumb and index finger. Snap the wings upward until the plastic portion is completely separated. Peel away from the catheter allowing the catheter to fall down. The needle is not designed to break completely.
- Measure length of the catheter remaining outside of the skin. Subtract this measurement from total length of catheter. The remaining is the length of catheter in the patient and should approximate the previously calculated desired catheter insertion length. Make adjustments in catheter position as necessary.
- To ensure catheter patency, aspirate the catheter with a heparinized saline filled syringe to visualize blood return and then gently flush.
- Apply steri-strips over puncture site to secure catheter. Refer to nursing procedure for dressing guidelines.

- (d) Documentation:** Write a **procedure note** describing site, catheter type and length, tip location, patient response, and complications (if any). This information should be recorded on the PICC documentation form.
- (e) Radiographic confirmation of catheter tip location:** Use radio-contrast material (*e.g.*, Omnipaque 180TM) to visualize the catheter. Use 0.1 mL of contrast for VygonTM 27 gauge, and NeoPICCTM 1.9 and 2.8 Fr catheters. Immediately before the x-ray cassette is exposed, instill the contrast at the hub of the catheter, injecting slowly with a 3cc syringe. Prior to exposing the x-ray, place the involved upper extremity in a position of maximal abduction, or the involved lower extremity in a fully flexed position. After radiograph has been taken, withdraw the contrast and gently flush the catheter with saline (0.9%) before reconnecting IV tubing. If the tip of the catheter is still difficult to visualize, repeat the film with a slightly oblique view with the side of catheter placement elevated. Monitor catheter tip placement with weekly (q Monday) radiographs.
- (f) Proper location of catheter tip:** For catheters inserted through arm or scalp vein, tip should be in **SVC just above right atrium**. For catheters inserted through a leg

vein, catheter tip should be **in IVC, just below right atrium**. **The tip of a PICC should never be in the heart, because of the risk of perforation and cardiac tamponade.**

3. Guidelines for use:

- Appropriate infusates include crystalloids, alimentation fluid, lipids, continuous drug infusions, and albumin. **Other blood products should not be infused because of clotting and hemolysis.**
- All infusates must have heparin added at a concentration of 1 unit/cc. Minimal infusion rate is 1 cc/hr.
- PICCs 1.9 Fr and larger may be placed to heparin lock for short periods but are at increased risk of occlusion by clot. The dose is 0.6 cc heparin (10 u/mL) q4hr.
- Blood sampling from PICCs is not recommended
- For flushing, use a 3 or 5cc syringe for 1.9 Fr catheters, 3cc only for 27gauge.
- In event of fungal line infection, the catheter should be removed and replacement deferred until a negative blood culture has been obtained. Mild bacterial infections (*i.e.*, Staph epidermidis) may be treated with a PICC *in situ*. If a repeat blood culture is positive or the infant's condition worsens, the catheter should be removed.

4. Complications include:

- Infection, local or systemic
- Vascular perforation
- Atrial perforation with cardiac tamponade
- Thrombophlebitis
- Catheter leakage, breakage or perforation by needle; splitting or cracking at the hub
- Embolism of broken catheter
- Pleural effusion (chylous or IV fluid)

5. Catheter removal: There is a nursing procedure for catheter removal. The Resident or NNP will be contacted for catheter damage or a stuck catheter (*i.e.*, one that cannot be withdrawn). If a portion of a catheter is missing, obtain a stat "babygram" to locate the catheter embolus and notify the Attending or Fellow. For a stuck catheter, apply gentle tension and tape the catheter to the skin. Repeat hourly until the catheter is removed. Apply a warm compress to the affected extremity while removing the catheter.

CARE OF INDWELLING CATHETERS

1. Keep catheters filled with fluid and free of blood except when obtaining blood samples. As soon as possible after inserting the catheter, begin infusion of heparinized fluid (1unit/mL) through the catheter.
2. Cover catheter insertion site with antibiotic ointment on a dry gauze pad. The dressing should be changed daily and the site inspected for signs of infection. Catheter sites, umbilical or other, should neither be left exposed nor covered with an occlusive dressing, which may cause maceration.
3. A guide to the types of fluids to be used in UVCs, UACs and peripheral arterial catheters is given in Table 2.

Table 2. Guide for use of fluids in intravascular catheters.¹

<u>Infusion Fluid</u>	<u>UVC²</u>	<u>UAC³</u>	<u>Peripheral Arterial Catheter</u>
0.9% NaCl	+	+	+
0.45% NaCl	+	+	+
5% Glucose	+	+	+
6 to 12.5% Glucose	+	+	0
Ringer's Lactate	+	+	0
Calcium	+	+ ⁴	0
Antibiotics and Other Medications	+	+	0

(+ = acceptable; 0 = unacceptable)

¹ Do not give intravenous alimentation with lipids and/or amino acids via UVC or UAC.

² This guide assumes that it is known that the tip of the UVC is in IVC or right atrium and not in the portal system or the left side of the heart.

³ This assumes that it is known that the tip of the UAC is in proper position.

⁴ Give calcium into UAC as a push only in emergency situations.