QUICK GUIDE TO
Central Venous Access
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Historical Perspective

Early attempts to access the central venous circuit occurred in the early 1900s. Reports first described catheters advanced into the central circulation using the cubital and femoral veins. In 1929, Werner Forssmann actually advanced a 4 F ureteral catheter into his own heart through a widebore needle in his left cubital fossa. He then proceeded up several flights of stairs to Radiology to document this event. In 1956, Forssmann and others were awarded the Nobel Prize for Medicine for their work in advancing venous access techniques.

Aubaniac first described his 10-year experience with the use of subclavian catheters for the rapid infusion of resuscitation fluids in military casualties in 1952. However, it was not until Wilson et al reported on the advantages of measurement of central venous pressure in the maintenance of optimal blood volume nearly a decade later that interest in the use of central venous catheters really took off. The rapid development and wide use of central venous catheters were further enhanced by the landmark papers by Dudrick et al on the value of total parenteral nutrition.

Indications for Use – Central Venous Access Devices

- Rapid fluid administration – for example, in cases of:
  - multiple trauma
  - burns
  - extensive abdominal surgery
  - sepsis
- Administration of IV fluids requiring dilution within the central circulation to avoid vascular damage (i.e., chemotherapy, total parenteral nutrition)
- Administration of vasoactive and/or incompatible drugs
- Frequent blood sampling (in patients without an arterial line) and/or blood administration therapies
- Chronically ill patients in whom peripheral IV access is limited
- Central venous pressure (CVP) monitoring for assessment of intravascular fluid status
- Measurement of oxygen saturation levels in blood returning to the heart (SsvcO₂)
- Monitoring and access for either pre- or post- pulmonary artery catheter insertion (same insertion site)
Indications for Use – Central Venous Access Devices (continued)

Contraindications include patients with:
- Recurrent sepsis
- Hypercoaguable state where catheter could serve as a focus for septic or bland thrombus formation

Types of Central Venous Access Devices

A central venous catheter is, by definition, a catheter whose tip resides in the central circulation. There are various types of these catheters, but, for the purpose of this guide, we will focus on the short-term (< 30 days) IV access catheters that are made by various manufacturers, including Edwards Lifesciences.

Single-lumen or double-lumen catheters are often inserted for intermittent or continuous infusion of medication or fluid. They are applicable for the administration of a particular solution (i.e., chemotherapy, antibiotic, and/or nutritional therapies) in the hospital or home setting. Single-lumen catheters may lend themselves to administration of total peripheral nutrition (TPN) through a dedicated line.

Multi-lumen catheters allow for multiple therapies to be performed through a single venous access site and are often seen in the critical care environment. These catheters, although designed for short-term access, generally see much use during this period.

Introducers are used to direct and place intravascular catheters, especially pulmonary artery catheters (PAC), within a designated blood vessel. They may be left in place to serve as a central venous access after removal of the PAC.

Advanced Venous Access (AVA) devices combine the ability to insert PACs and to infuse multiple fluids in one multipurpose device.

Central Venous Catheters

Catheter Specifics

Polyurethane (commonly used for catheter body)
- Tensile strength, which allows for thinner wall construction and smaller external diameter
- High degree of biocompatibility, kink and thrombus resistance
- Ability to soften within the body
Central Venous Catheters
Catheter Specifics (continued)

Nursing Note
Acetone and isopropyl alcohol should be avoided when caring for these catheters.

Number of Lumens
- More than one lumen increases the functionality of a single site (benefit)
- Multilumen catheters may be more prone to infection because of increased trauma at the insertion site or because multiple ports increase the frequency of manipulation

CDC Guideline (1996)
Use a single-lumen central venous catheter, unless multiple ports are essential for the management of the patient.
Although one study showed that only a single port is often used in one half of the triple lumens placed, triple-lumen CVCs appear to be the most commonly placed central line in ICU.

Practical Point
Critically ill patients may need more IV access than that obtained with a single multi-lumen CVC. Two triple-lumen CVCs or an introducer and a CVC may be placed in the same vein or in two different veins. This procedure is referred to as a double stick.

Flow Characteristics
- Primarily determined by a catheter’s internal diameter and length, not by the size of the blood vessel into which the catheter is inserted
- Is often incorrectly assumed to be proportional to the catheter’s outside dimension
Flow rates are usually calculated with normal saline at a head height of 40" (101.6cm).
Central Venous Catheters
Catheter Specifics (continued)

Length
Various studies have shown that the average safe insertion depth for central venous catheterization from the left or right internal jugular or subclavian vein is 16.5 cm for the majority of adult patients.1 (This assumes correct tip placement above the right atrium.2)

Coatings
Catheter coatings may include the bonding of the catheter surface with antimicrobial and/or antiseptic agents to decrease catheter-related infection and thrombotic complications. Heparin-bonding process is one example; other agents reported in the literature include antibiotics such as minocycline and rifampin, or antiseptic agents like chlorhexidine and silver sulfadiazine. Materials, in particular metals, that are antimicrobial in minute amounts are called oligodynamic. One of the most potent of these is silver, with the antimicrobial form being silver ions. The bactericidal action of silver ions is effective against a broad spectrum of bacteria, including the common strains which cause infection and the more virulent antibiotic-resistant strains. Silver has been in medical use for decades and was used in systemic drugs before the advent of antibiotics. Today, silver is used routinely in antibacterial salves (silver sulfadiazine), to prevent infection and blindness in newborns (silver nitrate), and in medical devices and catheters. Antibiotic- and antiseptic-coated catheters have demonstrated reduced rates of catheter colonization and associated bloodstream infection in some clinical trials, but it is important to remember that heparin-induced thrombocytopenia and/or allergy to the antibiotic used on a catheter could result in patient morbidity. Additionally, there is always the possibility that antibiotic-resistant microorganisms may develop or that the catheter site becomes infected with other organisms, such as Candida.
Nursing Note

Heparin-induced thrombocytopenia is a reduction in platelets caused by antiplatelet antibodies. It occurs in approximately 0.4% of patients with heparin-coated catheters and has a high mortality and morbidity. Patients so afflicted must not receive any more heparin, in any form, until the heparin-associated antiplatelet antibodies are no longer detectable.

Timely Tip

Twelve patients in Japan who had a silver sulfadiazine-chlorhexidine catheter in situ developed anaphylactic shock. This was related to possible pre-exposure to chlorhexidine in skin creams.5

Other Considerations

■ Soft tip to avoid injury or perforation
■ Radiopaque
■ Depth markings on all catheters and guidewires

Technical Tip

Catheter softness is a function not only of the material, but also of the specific formulation of that material (often proprietary information). Triple lumen catheters need to be stiffer because more septations and a firmer plastic are needed to extrude a multi-lumen catheter.
CVC Port Designation

<table>
<thead>
<tr>
<th>DISTAL (OR LARGEST GAUGE)</th>
<th>MEDIAL</th>
<th>PROXIMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood administration</td>
<td>TPN or Medications</td>
<td>Medication administration</td>
</tr>
<tr>
<td>High volume fluids</td>
<td>Blood sampling</td>
<td>Blood sampling</td>
</tr>
<tr>
<td>Colloid fluid administration</td>
<td>Drug therapy</td>
<td>Drug therapy</td>
</tr>
<tr>
<td>Drug therapy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVP monitoring</td>
<td></td>
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</tr>
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</table>

These are suggestions only.

CVC Port Color Designation

<table>
<thead>
<tr>
<th>PORT</th>
<th>DOUBLE</th>
<th>TRIPLE</th>
<th>QUAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal</td>
<td>white</td>
<td>white</td>
<td>white</td>
</tr>
<tr>
<td>Medial (1)</td>
<td>blue</td>
<td>blue</td>
<td>blue</td>
</tr>
<tr>
<td>Medial (2)</td>
<td></td>
<td>gray</td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
</tr>
</tbody>
</table>

Introducers as a Central Line

Sometimes an introducer is used for central venous access or is left in place following the removal of a pulmonary artery catheter. Components of the introducer system usually include:

- Flexible polyurethane sheath
- Guidewire and dilator
- Side port
- Hemostasis valve

After insertion, the guidewire and dilator are removed, leaving the sheath in place. Fluids may be administered through the side port, while the hemostasis valve prevents bleedback and/or air embolization.

A single-lumen infusion catheter can be used with the introducer, placed through the hemostasis valve (after swabbing the valve with Betadine), to convert to a double-lumen access. An obturator should be used to safely occlude the lumen as well as to prevent air entry when the catheter is not in use.
### French Catheter Size Conversion

#### Overview

<table>
<thead>
<tr>
<th>Diameter</th>
<th>French Scale</th>
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<tbody>
<tr>
<td>.236</td>
<td>6.0</td>
</tr>
<tr>
<td>.249</td>
<td>6.3</td>
</tr>
<tr>
<td>.263</td>
<td>6.7</td>
</tr>
<tr>
<td>.288</td>
<td>7.3</td>
</tr>
<tr>
<td>.315</td>
<td>8.0</td>
</tr>
<tr>
<td>.341</td>
<td>8.7</td>
</tr>
<tr>
<td>.367</td>
<td>9.3</td>
</tr>
<tr>
<td>.393</td>
<td>10.0</td>
</tr>
<tr>
<td>.419</td>
<td>10.7</td>
</tr>
<tr>
<td>.445</td>
<td>11.3</td>
</tr>
</tbody>
</table>

#### French Scale
To determine French Size if instruments are oval or other shape:
Use strip of paper to measure the periphery then lay on the scale below.

#### Stubs Needle Gauge

<table>
<thead>
<tr>
<th>Inches Equivalent</th>
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<tbody>
<tr>
<td>.042</td>
</tr>
<tr>
<td>.049</td>
</tr>
<tr>
<td>.056</td>
</tr>
<tr>
<td>.065</td>
</tr>
<tr>
<td>.072</td>
</tr>
<tr>
<td>.083</td>
</tr>
<tr>
<td>.095</td>
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</tbody>
</table>
Insertion Sites

Typically, central venous catheters are inserted via the subclavian or internal jugular (IJ) veins. The subclavian vein begins at the lateral border of the first rib and arches through the space between the first rib and clavicle. It joins the internal jugular to become the innominate (or brachiocephalic) vein, which then flows into the superior vena cava to the heart. The subclavian vein can be approached either infraclavicularly (below the clavicle) or supraclavicularly (above the clavicle). Alternative sites include the external jugular and femoral veins.

RELATIONSHIP OF CLAVICULAR LANDMARKS TO VASCULAR ANATOMY

Note the natural “windows” for supraclavicular venipuncture: 1) supraclavicular triangle formed by the clavicle, trapezius, and sternocleidomastoid muscles, 2) clavicular sternocleidomastoid triangle formed by the two bellies of the sternocleidomastoid muscle and the clavicle.

(Reproduced with permission from Novak RA, Venus B: Clavicular approaches for central vein cannulation. Probl Crit Care 2:242, 1988.)
Right IJ, supraclavicular procedures and left infraclavicular procedures are preferred. Note the close proximity of arterial and venous structures. Venipunctures in the lateral region of the clavicle are more prone to arterial puncture, brachial plexus injury, and pneumothorax. Note the prominent thoracic duct and higher apex of the lung on the left and the perpendicular entry of the left IJ into the left subclavian vein.

(Reproduced with permission from Novak RA, Venus B: Clavicular approaches for central vein cannulation. Probl Crit Care 2:242, 1988.)

Sites for Central Venous Catheterization: Advantages and Disadvantages

**INTERNAL JUGULAR (58 - 99% SUCCESS RATE)**

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively short and direct pathway to heart (right IJ)</td>
<td>Not ideal for prolonged cannulation</td>
</tr>
<tr>
<td>High success rate</td>
<td>Uncomfortable for patient</td>
</tr>
<tr>
<td>Easy access from head of bed</td>
<td>Dressings difficult to maintain</td>
</tr>
<tr>
<td>Pneumothorax rare</td>
<td>Left IJ increases risk of thoracic duct injury</td>
</tr>
<tr>
<td>Easier control of bleeding</td>
<td>Poor landmarks in obese or edematous patients</td>
</tr>
</tbody>
</table>
## Sites for Central Venous Catheterization: Advantages and Disadvantages (continued)

### INTERNAL JUGULAR (58 - 99% SUCCESS RATE)

#### ADVANTAGES
- Continued chest compression during CPR possible

#### DISADVANTAGES
- Difficult access with tracheostomies
- More prone to collapse with volume depletion or shock
- Difficult access during emergencies when airway control is being established
- Carotid artery puncture relatively frequent
- Contraindications for patients with intracranial hypertension

### INFRACLAVICULAR (85-99% SUCCESS RATE)

#### ADVANTAGES
- Easier to maintain dressings
- More comfortable for patient
- Better landmarks in obesity
- Large vein less collapsible during hypovolemia

#### DISADVANTAGES
- Higher risk of pneumothorax
- Compression of bleeding site difficult
- Long pass from skin to vein

### SUPRACLAVICULAR (85-99% SUCCESS RATE)

#### ADVANTAGES
- Low incidence of pneumothorax
- High success rate
- Easier to pass catheter
- Accessible from head of bed
- Good landmarks
- No interference with chest compression
- Anatomic landmarks constant
- Short path from skin to vein

#### DISADVANTAGES
- Control of bleeding difficult
- Pneumothorax possible
- Uncomfortable for patient
- Not ideal for prolonged access
- Dressing and catheter maintenance difficult
- Thoracic duct puncture possible
- Not ideal approach when airway control is being established
- Not ideal for temporary hemodialysis
Sites for Central Venous Catheterization: Advantages and Disadvantages (continued)

EXTERNAL JUGULAR (60-90% SUCCESS RATE)

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part of surface anatomy</td>
<td>High failure rate</td>
</tr>
<tr>
<td>Clotting abnormalities not prohibitive</td>
<td>Not ideal for prolonged access</td>
</tr>
<tr>
<td>Pneumothorax avoided</td>
<td>Uncomfortable for patient</td>
</tr>
<tr>
<td>Access from head of table</td>
<td>Dressing maintenance difficult</td>
</tr>
<tr>
<td>Prominent in elderly</td>
<td>Poor landmarks in obese and edematous patients</td>
</tr>
<tr>
<td></td>
<td>Unsuccessful in young patients</td>
</tr>
<tr>
<td></td>
<td>Difficult for threading central catheters</td>
</tr>
</tbody>
</table>

(Reproduced with permission from Novak RA, Venus B: Clavicular approaches for central vein cannulation. Probl Crit Care 2:242, 1988.)

Practical Point

Catheters inserted in the femoral vein and advanced into the inferior vena cava may be utilized as a second alternative to the superior vena cava, except for emergency IV fluid resuscitation or for superior vena cava injuries. Cannulation of this vein usually has a high success rate. This approach may, however, have the disadvantage of requiring longer catheters; the catheter tip should lie in the inferior vena cava for infusions and should reach the level of the diaphragm for the purpose of central venous pressure monitoring.

Research Riches

In a study of anesthetized, mechanically ventilated patients who were in a 10º head down position and receiving fluid loading, an inverse relationship between a large external jugular vein (as measured with an ultrasound imaging machine) and a small internal jugular vein was found. Mean IJV diameter was 17.4 mm (range 4-30 mm). There was no correlation between weight, height, or neck size and IJV diameter.
Sites for Central Venous Catheterization: Advantages and Disadvantages (continued)

**CDC Guideline (1996)**
- Weigh the risk and benefits of placing a device at a recommended site to reduce infectious complications against the risk of mechanical complications (e.g., pneumothorax, subclavian artery puncture, subclavian vein laceration, hemothorax, thrombosis, air embolism, catheter misplacement).
- Use subclavian, rather than jugular or femoral, sites for central venous catheter placement unless medically contraindicated (e.g., coagulopathy, anatomic deformity).

Central Venous Catheterization via the Seldinger Technique

**ONE**
- Enter vessel with 22 gauge locating needle and attached 5ml syringe
- Upon aspiration of dark venous blood, remove needle and syringe

**TWO**
- Attach 5ml syringe to 18 gauge catheter over 20 gauge needle assembly
- Insert needle and relocate vein previously entered
- Upon aspiration of venous blood, remove needle and syringe, leaving the 18 gauge catheter in place.
- Insert guidewire into already placed 18 gauge catheter
Central Venous Catheterization via the Seldinger Technique (continued)

THREE
■ Remove catheter, leaving the guidewire in place

FOUR
■ Enlarge puncture site, if necessary with small scalpel

FIVE
■ Further enlarge the insertion site and vessel by threading a dilator over the guidewire
■ Leaving the guidewire in place, remove the dilator

SIX
■ Thread central venous catheter over the guidewire.
■ Remove guidewire


Patient Preparation

Catheters can be inserted in a variety of settings under various conditions. Recently, it has been shown that the setting of catheter placement may not be as critical a factor in minimizing infection risk as the use of maximal barrier precautions. Two studies have shown the use of maximal barrier precautions (cap, mask, gown, gloves, and large drape) decrease the colonization of the catheter surface at the time of insertion, thereby decreasing the risk for catheter-related sepsis.

**CDC Guideline (1996)**

Use sterile technique, including a sterile gown and gloves, a mask, and a large sterile drape (i.e., maximal barrier precautions), for the insertion of central venous and arterial catheters. Use these precautions even if the catheter is inserted in the operating room.
Patient Preparation (continued)

The skin should be cleaned before insertion using an antiseptic agent to kill or inhibit growth of microorganisms. Popular antiseptics include:

**70% ALCOHOL**

**ADVANTAGES**

- Fast kill
- Very effective against gram-negative and gram-positive bacteria
- Effective fat solvent

**DISADVANTAGES**

- Not effective against spores
- Must rub the site vigorously for at least one minute
- Drying nature of alcohol.

**2% TINCTURE OF IODINE**

**ADVANTAGES**

- Effective against the same organisms as 70% alcohol
- Prolonged contact may even kill certain fungi and spores

**DISADVANTAGES**

- May cause skin irritation
- Must be removed from skin before catheter is placed

**10% POVIDONE-IODINE (IODINE SOLUTION)**

**ADVANTAGES**

- Reduced toxicity
- Less skin irritation than iodine tincture

**DISADVANTAGES**

- Contact time of 2 minutes necessary for optimal microbial kill
- Neutralized in presence of blood and pus

**CHLORHEXIDINE**

**ADVANTAGES**

- Active against gram-positive and gram-negative organisms and viruses
- Residual activity up to 6 hours

**DISADVANTAGES**

- Can be inactivated by compounds found in hard water and soap
- Allergic reactions reported

**Patient Position**

**15 - 30 DEGREES TRENDELENBURG**

- Increases venous return by approximately 37%
- Increases intrathoracic pressure
- Helps prevent inadvertent air embolization
- Not always well tolerated by cardiac patients
- Not necessary when jugular venous distention (JVD) present in supine position (right-sided failure)
Patient Position (continued)

VALSALVA MANEUVER (FORCED EXPIRATION AGAINST CLOSED GLOTTIS)

- Increases cross-sectional area of jugular vein by approximately 25%
- May be accomplished in ventilated patients by causing a forced inflation via an Ambu bag

“BUMP” POSITION

Head turned to the contralateral side and a rolled towel placed in the back.

INFRACLAVICULAR APPROACH TO THE RIGHT SUBCLAVIAN VEIN

The patient is positioned with a rolled towel between the scapulae to increase the distance between the clavicle and the first rib.
Catheter Tip Placement

Triple-lumen catheters should be inserted so that the tip is approximately 2 cm proximal to the right atrium (for right-sided approaches) and similarly placed or well within the innominate vein (for left-sided approaches), with the tip parallel with the vessel wall. A chest x-ray must be done post insertion, as it provides the only definitive evidence for catheter tip location.

Probably the most important factor in the prevention of complications is the location of the catheter’s tip. The pericardium extends for some distance cephalad along the ascending aorta and superior vena cava. In order to guarantee an extrapericardial location, the catheter’s tip should not be advanced beyond the innominate vein or the initial segment of the superior vena cava. (It is important to note that a portion of the superior vena cava lies within the pericardium.)

Some practitioners may prefer a deep SVC placement (within the lower third of the SVC), but nearly half the length of the SVC is covered by pericardial reflection that slopes downward toward its lateral edge. To avoid the risk of arrhythmias and tamponade, the tip of a CVC should lie above this reflection and not in the right atrium.

Clinical Concern

It should be noted that even x-ray confirmation of the catheter in a location above the pericardial reflection does not guarantee against possible tamponade. Cases of perforation with hydromediastinum and cardiac tamponade have been reported, with the site of extravasation being as distal as the subclavian vein. One concern with the multi-lumen catheter is the necessity of advancing it somewhat further than a normal catheter to ensure that the proximal opening is within a central vein.

Tips to assure catheter tip not extravascular or against a wall might include:
- Syringe aspiration yields blood freely
- Venous pressure fluctuates with respiration
- Advancement of the catheter is unhindered
Clinical Considerations: Insertion

**RECOMMENDED EQUIPMENT**

Central venous catheter insertion kit:
- Multi-lumen CVC
- 22 gauge locator needle
- 18 gauge catheter over 20 gauge needle assembly
- Guidewire
- Dilator
- 5 cc syringes
- Scalpel
- Lidocaine with needle and syringe
- Needleless injection caps
- Suture material/needle
- Gauze
- Sterile drapes (large)
- Antiseptic
Clinical Considerations: Insertion (continued)

Additional items:
- **Sterile gloves, sterile gowns, masks and caps** for everyone in room
- Dressing materials (dressing per hospital policy, nonallergenic tape)
- Heparin flush solution
- Pressure monitoring setup for **CVP determination**, if desired (flush solution, pressure bag, pressure tubing, transducer and holder, stopcocks, monitor cable, leveling device)

**CLINICAL RESPONSIBILITIES**

- Confirm orders
- Obtain informed consent from patient or designated power of attorney
- Provide further information as requested by patient or family members
- Check equipment to monitor patient (EKG, blood pressure, pulse oximetry, etc)
- Assemble equipment and move into patient room
- Position the patient and provide privacy
- Assist with insertion of catheter under aseptic technique
- Monitor patient vital signs during insertion
- Assess patient comfort and intervene appropriately
- Protect the patient by:
  - Assuring compliance with **maximal barrier precautions**
  - Calling in support personnel (i.e., respiratory therapy) as necessary
  - Recording vital signs, rhythm strips or waveform traces, $\text{SaO}_2$ values, etc.
  - Securing the catheter and dressing the site per hospital protocol
  - Ordering **chest x-ray** post-insertion
  - Running fluids at **TKO** until chest x-ray results available
  - Contacting clinician to read chest x-ray or to inform of abnormal findings
  - Documenting site, **depth of insertion**, and the patient’s response to the procedure on progress/nursing notes
Clinical Considerations: Insertion (continued)

**CDC Guideline (1996)**
- Wear non-latex or latex gloves when inserting an intravascular device as required by the Occupational Safety and Health Administration (OSHA) Bloodborne Pathogens Standard.
- Do not routinely use cutdown procedures as a method to insert catheters.
- Cleanse the skin site with an appropriate antiseptic, including 70% alcohol, 10% povidone-iodine, or 2% tincture of iodine, before catheter insertion. Allow the antiseptic to remain on the insertion site for an appropriate length of time before inserting the catheter.
- When tincture of iodine is used for skin antisepsis before catheter insertion, it should be removed with alcohol.
- Do not palpate the insertion site after the skin has been cleansed with the antiseptic (this does not apply to maximum barrier precautions during which the operator is working in a sterile field).
- Record the date and time of catheter insertion in an obvious location near the catheter insertion site (e.g., on the dressing or on the bed).

Insertion Complications
Mechanical complication rates range from 1% to 10%, although rates as high as 15% have been reported when the access is placed emergently. Complications related to insertion can manifest themselves within minutes following insertion or may not be obvious for several days.

**Research Riches**
One study shows, the strongest predictor of a complication is a failed catheterization attempt. Many clinicians feel that three attempts are enough, and then it is time to ask another clinician to attempt catheterization from another site.
Insertion Complications (continued)

Complications of Central Venous Catheterization

Air Embolism

- May be associated with insertion process
- Patient positioning (Trendelenburg)
- Often related to disconnection of tubing or at catheter removal
- **Valsalva maneuver** (forced exhalation)
- Patients who are hypovolemic or snore are at highest risk
- Can occur after removal, if subcutaneous tract made by catheter has failed to close
- Sudden onset tachycardia, pulmonary hyper-, or systemic hypo-tension
- Neurologic deficit or potentially fatal position; **aspirate air** if CVC still in place
- Place patient in left lateral decubitus

Arterial Puncture

- Arterial and venous proximity
- Local pressure may be enough to stop bleed
- Variable venous anatomy
- Appearance of bright red, pulsatile blood
- Hematoma may resolve or evolve into false aneurysm or arteriovenous fistula

**Clinical Concern**

The rare complication of tracheal puncture may also occur with internal jugular cannulation attempts, especially in patients with **endotracheal tubes**, since the inflated cuff brings the tracheal wall closer to the adjacent veins.
Insertion Complications (continued)

Arrhythmias
- **Transient** atrial/ventricular arrhythmias
- Usually related to over insertion of guidewire or catheter, with impingement of the tips of these devices in the region of the right bundle branch

Cardiac Tamponade/Pericardial Effusion/Hydromediastinum
- Fluid in pericardial cavity due to perforation of structures by catheter
- Cardiovascular collapse once critical volume reached
- Infusion of fluid through catheter prior to placement confirmation
- Immediate pericardiocentesis

Pneumothorax/Hydrothorax
- Puncture of lung tissue
- Diminished breath sounds, tachypnea
- Atmospheric pressure causes air to enter and collapse portion of lung
- Not clinically detectable if < 20%
- May heal itself or require chest tube

Malpositioned Catheters
- Arrhythmia, venous thrombosis
- Cardiac tamponade
- Falsely elevated pressure measurements
- Delivery of infusate into thoracic cavity
- Vascular erosion and perforation

**Physiologic Fact**

The most common malposition occurs when a catheter inserted via the infraclavicular route goes into the homolateral **internal jugular vein** with the tip of the catheter facing oncoming blood flow. Other vessels in which a catheter might become malpositioned include the internal mammary, axillary, vertebral, and the greater azygos veins.
Pericardial tamponade caused by central venous catheter perforation of the heart is a catastrophic complication that can be prevented by attention to proper positioning of the catheter tip proximal to the cardiac silhouette. In a recent study (1998), it was determined that only 31% of the physicians studied who insert central venous catheters were aware that cardiac tamponade is a potential complication, and only 10% recalled ever seeing or reading the package inserts that warned of cardiac tamponade. This is in spite of the fact that in 1993 the Food and Drug Administration (FDA) sent a three-volume video entitled “Central Venous Catheter Complications” to all hospitals where central venous catheters were inserted. This same study detailed 25 previously unreported cases of cardiac tamponade after placement of central venous catheters in a nineteen-month period. Eighty percent of the patients died and 12% remain in a persistent vegetative state. Post-insertion chest x-rays were available in 23 cases. All post-insertion chest x-rays showed the tip of the catheter to be within the pericardial silhouette.

Next, thirty local radiologists were interviewed. Ninety percent of them were not aware that the tip of the central venous catheter should be located outside of the pericardial silhouette on the radiograph. None of the inserting physicians believed that it was his or her responsibility to check the chest x-ray for catheter placement.

Pulmonary symptoms were common, with 8 patients complaining of chest tightness, 12 of shortness of breath, and 15 were noted to have air hunger up to 6 hours prior to significant changes in vital signs occurring. Fourteen patients developed tachycardia and 8 were noted to be bradycardic. All patients developed significant, unexplained hypotension as a result of cardiac tamponade. Many of these patients were intubated as part of their resuscitation. Seven patients developed EKG changes consistent with inferior wall ischemia or injury.
In all cases, the clinicians treated the patient for myocardial ischemia and did not suspect cardiac tamponade. Ten patients developed new or different non-specific ST- and T-wave changes. Five developed worsening of their hypotension when nitrates were administered.

This study is particularly discouraging, because the FDA and catheter companies have attempted to warn physicians of the danger of cardiac tamponade through the use of talks, posters, videos and package insets. However, this survey and surveys done previously have shown that a minority of physicians were aware of this potential complication. More importantly, few physicians are aware that cardiac tamponade is preventable if the tip of the central venous catheter is outside the pericardial shadow on the chest radiograph. Any patient with a CVC in place who develops unexplained hypotension, chest tightness, or shortness of breath should have an emergency echocardiogram to rule out cardiac tamponade.

Clinical Responsibilities

- Observe patient for any signs of cardiopulmonary distress
- Auscultate lungs every 2-4 hours; record findings on nursing flow sheet/progress notes
- Observe daily chest x-ray and record interpretation as to catheter position in the nursing notes/progress notes
- Include depth of catheter insertion daily in nursing notes/progress notes
- Observe and record any change in neurological status.
- Report any change in patient condition to the clinician, as appropriate
- Maintain emergency cart, including thoracentesis, pericardiocentesis, and chest tube insertion trays
Delayed Complications

The most common delayed complications of vascular access device insertion are **thrombosis** and **infection**. These two complications are somewhat related, as thrombotic complications are common in catheterized veins and are often associated with catheter sepsis.

**Thrombosis**

All catheters are thrombogenic. Within seconds after insertion, much of the catheter body is coated with body fluids and proteins. Platelets adhere and thrombus forms.

Catheters can become encased within 5-7 days, forming a **fibrin sheath**. Some investigators state that a fibrin sleeve is found on 100% of subclavian catheters in postmortem examinations and in patients studied with cinefluoroscopy.

**Clinical Concern**

Three common organisms causing catheter-related infections (*S. epidermidis, S. aureus, C. albicans*) adhere well to fibrin and fibronectin found in fibrin sheaths. These organisms also produce a coagulase enzyme (slime) that further enhances their adherence on the vascular catheter as well as protects them from the action of antibiotics.

Mural (wall) thrombi may form on the catheter and/or on the wall of the vessel. They may develop within 48 hours of cannulation, and there have been many case reports of such thrombi breaking off and resulting in **pulmonary emboli**. Some of these cases have resulted in mortality 4-5 days after insertion. Additionally, catheter removal may precipitate dislodgement of such thrombi.

Mangano found that the use of catheters with heparin-bonding offers considerable protection from thrombosis for 24 hours or longer. Thus the use of such catheters may be efficacious in minimizing the risks of embolism, infarction, and occlusive thrombosis over prolonged periods.

The use of **prophylactic anticoagulants** is variable. In a recent (1998) review of the literature, it was found that prophylactic use of **heparin** significantly decreases central venous catheter-related thrombosis, decreases bacterial colonization of the catheter, and may decrease catheter-related bacteremia. Low molecular weight heparin seems to have less propensity for causing heparin-induced thrombocytopenia and is 99% bioavailable.
Delayed Complications (continued)

Therapies may include:
- Mix heparin with TPN solution (3U/mL)
- Give heparin IV every 6 or 12 hours (5,000 U)
- Give low molecular weight heparin subcutaneously every day (2,500 U)

Catheter Occlusion

Catheter occlusion may be a result of fibrin sheath formation and/or thrombus at the tip of the catheter but has also been associated with blood clots, lipid deposits or precipitates within the catheter lumen. Fibrin sheath formation is significant in that the sheath may eventually totally encase the catheter and affect the functional ability of the catheter. Withdrawal occlusion may occur if the fibrin sheath acts as a flap which blocks the tip of the catheter when blood withdrawal is attempted, and then opens up with injection.

There is also evidence that partial occlusion is related to a residue of blood products deposited within some access devices each time blood is aspirated or infused.

Other theories include drug precipitation. These occlusions may result from:
- Inadequate flushing between incompatible medications
- Simultaneous administration of incompatible medications
- Medications administered in a concentration exceeding that required for stability

Attempts to clear catheter occlusions include the use of fibrinolytic agents. Catheter patency can often be restored if the solubility of the fluid components is changed by altering the pH through the use of 0.1 N hydrochloric acid and sodium bicarbonate.

Clinical Concern

The use of lipid-containing TPN, commonly referred to as three-in-one, has been shown to be responsible for a unique type of catheter precipitate occlusion. An aggregation that occurs with lipid/parenteral nutrition admixtures causes the development of deposits that result in sludging in the catheter lumen and eventual occlusion. The use of an ethanol (70% ethyl alcohol) solution as a means of dissolving fat (the main component of the occlusion) has been reported.
Delayed Complications (continued)

Infection

It is estimated that 200,000 nosocomial (hospital-acquired) bloodstream infections occur each year; most of these infections are related to the use of an intravascular device. These infections are associated with increased mortality and morbidity, prolonged hospitalization and extended intensive care unit stays, and greater hospital costs. It has been estimated that each bloodstream infection costs the hospital approximately $6,000- $40,000 and increases the length of stay by an additional 24 days per survivor.9

Catheter-related bloodstream infection – isolation of the same organism by a semiquantitative technique from a removed catheter associated in time with the recovery of the same organism from properly collected blood cultures (preferably drawn from a peripheral vein) in a patient with accompanying clinical symptoms and no other apparent source of infection.

Practical Point

There are rarely more than 50-100 colony-forming units (CFU) at the site of insertion of a peripheral venous catheter on the arm or wrist. On CVC sites located on the chest or neck, there are as many as 1000 to 10,000 CFU/site, especially in long-term ICU patients.10

Research Riches

All other factors being equal, the general feeling is that the longer the line stays in place, the more likely the possibility of infection. However, more recent data suggest that the daily risk of infection remains constant.11
Over the past two decades, there has been a marked change in the distribution of pathogens reported to cause bloodstream infections (BSIs). Since the mid-1980s, an increasing portion of nosocomial BSIs have been due to **gram-positive**, rather than gram-negative, species. The increase in nosocomial BSIs during the past decade is largely due to significant increases in four pathogens:

- **Coagulase negative staphylococci (CoNS)**, including *Staphylococcus epidermidis*
- **Candida species**
- **Enterococci**
- **Staphylococcus aureus**

(N.B. Coagulase-negative organisms are gram-positive organisms.)

Prior to 1986, *S aureus* was the most frequently reported pathogen causing nosocomial BSIs. Currently, **coagulase negative staphylococci**, particularly *S. epidermidis*, have become the most frequently isolated pathogens in catheter-related infections. The prevalence of these organisms also shows that the **hands of healthcare workers** and the **flora of patients’ skin** are likely to be the predominant sources of pathogens for most catheter-related infections.

The **pathogenesis** of central venous catheter colonization and related bloodstream infection is not completely understood. The leading theories include:

- Migration of skin organisms through the cutaneous catheter tract
- Contamination of the hub
- Hematogenous seeding (from pneumonia, urinary tract infections, etc)
- Contaminated infusate

(Reproduced with permission from Maki DG: Infections due to infusion therapy. (Chapter 40) in *Hospital Infections* (Bennett JV, Brachman PS, eds) Boston: Little, Brown and Co, 1992.)
Delayed Complications (continued)

**Research Riches**

Recent findings suggest that duration of catheterization influences which of the mechanisms predominate. Hub contamination is the more likely mechanism for infection for long-term catheters (i.e., in place > 30 days) while skin contamination is the most likely cause for short-term catheters (i.e., <10 days).\(^{12}\)

**Timely Tip**

Manipulations of the delivery system, especially the administration set, appear to provide a highly effective means for access of microorganisms to in-use infusate. This was illustrated by a spate of nosocomial outbreaks across the US traced to in-use contamination of a newly released intravenous anesthetic, propofol (Diprivan). The solution provides an almost uniquely rich medium for rapid microbial growth. (It is a lipid formulation, like intralipids administered with TPN.)

**Timely Tip**

A recent (1998) editorial left this “take home” message. “Antibiotic- and antiseptic-coated catheters have demonstrated reduced rates of catheter colonization and associated bloodstream infection. However, if all other measures are optimized, their value remains to be proven.” “...these devices may best serve high-risk populations... patients undergoing change of a central venous catheter over a guidewire and patients for whom the consequence of infection is great... or when the duration of CVC use is anticipated to exceed 5 days.”\(^ {13}\)

**CDC Guideline (1996)**

In adults, consider use of a silver-impregnated collagen cuff or an antimicrobial- or antiseptic-impregnated central venous catheter if, after full adherence to other catheter infection control measures (e.g., maximal barrier precautions), there is still an unacceptably high rate of infection.

**Diagnosis**

The best tests for venous access device infection are direct specimens of the device itself and any attached material or organisms, and these tests are possible only after the catheter is removed. Otherwise, there is no identified gold standard for diagnosing catheter-related infections.
Delayed Complications (continued)

**DIAGNOSIS OF CATHETER-RELATED INFECTION**

Semi-quantitative catheter culture (Maki)
- Catheter removed after skin is cleaned
- Most widely used, best studied
- At least 5 cm of tip and the catheter segment beginning 1-2 mm inside the point of the skin-catheter junction are cultured
- Cutaneous segment may be better predictor than tip
- Only outside of catheter cultured
- Only determines catheter colonization
- Catheter segments are rolled on agar plate
- **Catheter must be removed**

Quantitative catheter culture
- Catheter segment flushed with broth
- Most sensitive
- Segment then immersed in broth
- Both luminal and external surfaces
- Sonicated to release organisms
- **Catheter must be removed**

Quantitative blood cultures
- Blood cultures simultaneously drawn from catheter and peripheral IV sample
- Positive = catheter blood sample colonies > 5x peripheral
- Compares concentration of organisms
- **Does not require removing CVC**

Catheter exchange
- Change catheter over wire
- Remove new catheter if positive culture obtained
- Culture catheter
- The critical step in the treatment of central line infections is to remove the involved catheter. Antimicrobial therapy usually is given adjunctively, but is no substitute for catheter removal.
Delayed Complications (continued)

Clinical Responsibilities: Delayed Complications

- Monitor patient temperature frequently
- Monitor WBC levels (with differential) at least on a daily basis
- Administer medications, as ordered, to prevent thrombosis and infection
- Collect blood or tip cultures as ordered, using sterile technique
- Monitor coagulation parameters as ordered
- Report abnormal findings to the clinician

**CDC Guideline (1996)**

Do not routinely perform surveillance cultures of patients or of devices used for intravascular access.

Catheter Exchange

There are a wide variety of practices concerning the changing of short-term percutaneously-inserted CVCs. Policies run the gamut from routine changes every 3-4 days to leaving the catheter in place until a complication develops or it is no longer needed.

**Research Riches**

A recent controlled study showed that routine replacement of CVCs every three days does not prevent infection. A prospective, randomized trial concluded that routine 72-hour catheter exchange does not confer an advantage over 7-day catheter exchange in the prediction of central venous infection in a critically ill patient requiring multiple lumen central venous access.  

Central venous catheters can be exchanged for a variety of reasons. Replacement of these catheters can be achieved by using *de novo* (in a new site) percutaneous placement or by using the Seldinger technique to change the catheter over a guidewire in the same site. In general, *exchanging catheters over a guidewire* may be associated with fewer mechanical complications and no increased risk of infection, compared to new-site venipuncture.
Catheter Exchange (continued)

However, these findings have not been consistently documented, and complications may relate to clinician experience.

**Research Riches**

Exchanging catheters over guidewires or at new sites every three days is not beneficial in reducing infections, compared with catheter replacement on an as-needed basis.\(^{15}\)

**CDC Guideline (1996)**

- Do not routinely replace non-tunneled central venous catheters as a method to prevent catheter-related infections.
- Use guidewire assisted catheter exchange to replace a malfunctioning catheter or to convert an existing catheter if there is no evidence of infection at the catheter site.
- If catheter-related infection is suspected, but there is no evidence of local catheter-related infection (e.g., purulent drainage, erythema, tenderness), remove the existing catheter and insert a new catheter over a guidewire. Send the removed catheter for semiquantitative or quantitative culture. Leave the newly inserted catheter in place if the catheter culture result is negative. If the catheter culture indicates colonization or infection, remove the newly-inserted catheter, and insert a new catheter at a different site.
- Do not use guidewire assisted catheter exchange whenever catheter-related infection is documented. If the patient requires continued vascular access, remove the implicated catheter and replace it with another catheter at a different insertion site.

It has been a common practice to obtain a chest x-ray after catheter exchanges over a guidewire.
However, there has recently been controversy concerning this policy. Some clinicians now feel that chest x-rays are unwarranted after uncomplicated guidewire exchanges in hemodynamically stable, monitored patients. Rationale includes:

- The results of several studies showing no complications
- The feeling that many complications would be picked up by clinical signs
- Patients requiring CVC generally have routine chest x-rays, usually within 48 hours of exchange

Clinical Responsibilities: Catheter Exchange

- Assist with catheter exchanges, as per insertion responsibilities
- Assist with regloving and redraping the site between removal and reinsertion

CVC Removal

Central venous catheters may be removed for a variety of reasons, including discontinuation of therapy and transfer to a subacute environment. Removal of the CVC generally is performed by house staff or nurses. It should precede the patient’s transfer, as this removal is ideally performed in a monitored situation.

Research Riches

The removal of a central venous catheter can be complicated by a rare but potentially life-threatening neurocardiopulmonary distress, according to one recent (1998) study. The clinical courses of eight patients who had CVCs removed were studied. The major complications were: neurologic paresis or coma (4 patients), respiratory failure (4 patients), and shock (2 patients). One patient died from pulmonary sepsis. The overall mortality rate was 12.5%. The authors felt this syndrome to be an unappreciated complication of central venous catheter removal. 16
CVC Removal (continued)

CDC Guideline (1996)
- Remove any intravascular device as soon as its use is no longer clinically indicated
- No recommendation for removal of central catheters inserted under emergency conditions where breaks in aseptic technique are likely to have occurred

Clinical Considerations: Removal

RECOMMENDED EQUIPMENT
- Sterile gloves
- Suture removal set
- Sterile dressing material
- Antibiotic/antiseptic ointment
- Non-allergenic tape
- Appropriate waste container
- Culture container

CLINICIAN RESPONSIBILITIES
- Confirm order
- Explain procedure to the patient and/or family members
- Remove existing dressing material and dispose of it in the appropriate waste container. Clip any sutures
- Discontinue existing IV solutions running through CVC; switch to alternate site
- Position the patient in a head-down position, if tolerated; at least keep as flat as possible

Clinical Concern
This is especially important if the patient is dehydrated, as a low CVP may generate a sucking force of air into the systemic circulation.

- Observe careful aseptic technique as you remove the catheter. Change gloves
- Slowly and continuously remove catheter while the patient holds his/her breath to prevent air embolization
**Clinical Concern**

If patient is intubated, have respiratory therapist provide a forced inspiration via Ambu bag.

**Occlude** catheter lumen or exit wound immediately, again to prevent air entry.

Be careful applying **pressure to neck sites** as this could:
- Dislodge arteriosclerotic plaques or thrombus in the carotid artery, causing a **stroke** and/or
- Cause a **vasovagal reflex**, leading to acute onset bradycardia and hypotension

Apply **antibiotic ointment** to the exit wound to seal the track opening.

Apply **air-tight occlusive dressing**: leave in place for at least 12 hours, preferably 24-72 hours.

**Research Riches**

The literature report cases of air embolization after line removal due to a long-standing catheter track.\(^{17}\)

Collect appropriate cultures. (This may require a second person to cut the tip while the first secures the site.)

Patient should remain **lying flat in bed** for 30 minutes after CVC removal.

Note: a **suture** may be needed to close a large and long-standing catheter track.

**Chart** patient’s response to the procedure, any untoward complications, and the type of culture sent.

**Physiologic Fact**

Any patient that has an opening between the right and left sides of the heart is especially at risk if air enters the venous system. Although the blood flow through an opening is usually left-to-right since pressures are higher on the left side, it is possible for the air to enter the left side of the heart through a **patent foramen ovale** (the hole in the atrial septum that normally closes at birth) or through **shunts in the pulmonary circulation**. A very small amount of air is necessary to cause neurologic symptoms as the air enters the right carotid artery and goes to the brain. This causes left-sided weakness. The only reason the right carotid is usually involved is that it is the first upward artery off the aortic arch.
Site Care

Care of the catheter site is considered to be of primary importance and is believed to play a critical role in decreasing the risk for catheter-related sepsis. Universal standards for care of the catheter site have not been established. Unresolved issues include use of **ointments** and **antiseptic agents**, **dressing type**, and **frequency of dressing changes**.

Although exact protocols for site care vary from institution to institution, they all call for:
- Removal of the old dressing
- Inspection of the site and surrounding area
- Cleansing of the site
- Covering the site with a sterile dressing

Sterile **gloves and masks** should be worn during dressing changes.

**CDC Guideline (1996)**
- Wash hands before and after palpating, inserting, replacing, or dressing any intravascular device
- Wear non-latex or latex gloves when changing the dressings on intravascular devices
- No recommendation for the use of sterile versus non-sterile clean gloves during dressing changes

Site Inspection

Any signs or symptoms that might indicate an infection should be reported at once. However, these signs are not always indicative of infection. Signs of infection may include **redness** or **exudate**. However, many catheters exhibit **slight erythema** at the site without necessarily being infected. Conversely, the immunosuppressed patient may show no signs of infection even when infection is present. **Fever, however, in a patient with a CVC is usually attributable to the catheter until proven otherwise.**
Site Inspection (continued)

**CDC Guideline (1996)**
- Palpate the catheter insertion site for tenderness daily through the intact dressing
- Visually inspect the catheter site if the patient has development of tenderness at the insertion site, fever without obvious source, or symptoms of local or bloodstream infection
- In patients who have large, bulky dressings that prevent palpation or direct visualization of the catheter insertion site, remove the dressing, visually inspect the catheter site at least daily, and apply a new dressing

**Site Cleansing**

The catheter exit site should be cleansed with an appropriate antiseptic agent that includes 70% alcohol and 10% povidone-iodine. (Povidone-iodine has replaced iodine for use in the clinical setting.)

Cleansing with an appropriate antiseptic solution should proceed in a circular pattern, working outward from the insertion site. Typically, cleansing begins with the application of 70% isopropyl alcohol to remove skin oils and cells, exposing the lower skin layers to the antimicrobial activity. **Alcohol needs to remain wet on the skin for at least 1 minute.** Although alcohol provides the most rapid and greatest reduction in microbial counts on the skin, it does not have any residual antimicrobial activity.

**Research Riches**

One study by Maki found no significant antimicrobial benefit for defatting the skin during dressing change.18

**Technical Tip**

Acetone, alcohol and ether have been shown to weaken polyurethane and silicone materials.

After the alcohol (if used), the insertion site is usually prepped with povidone-iodine. This material **must remain in contact with the skin for at least 2-5 minutes** before the procedure in order to achieve adequate microbial count reductions.
The sustained release of free iodine from povidone-iodine has an antibacterial effect. The antimicrobial activity of povidone-iodine is significantly reduced by the presence of blood, mucous, and other organic matter.

**CDC Guideline (1966)**
- Wash hands before and after palpating, inserting, replacing, or dressing any intravascular device
- Cleanse the skin site with an appropriate antiseptic, including 70% alcohol, 10% povidone-iodine, or 2% tincture of iodine. Allow antiseptic to remain on the insertion site for an appropriate length of time

Chlorhexidine 0.5% in 70% isopropyl alcohol has recently been promoted for use as a skin disinfectant. Chlorhexidine leads to residual antibacterial activity that persists for hours after application, and it is not affected by protein.

**Research Riches**
In a prospective, randomized study by Maki, in which he looked at the efficacy of several solutions, 2% chlorhexidine before insertion and for post-insertion site care substantially decreased the incidence of catheter-related infection.19

FDA Alert! Chlorhexidine allergy resulting in anaphylactic shock has been reported.

The use of ointments in the care of CVCs is controversial. Although it would appear that the use of an antimicrobial ointment would be beneficial, clinical trials have not conclusively confirmed the benefit of such ointments. Their use has been further complicated in that an increase in frequency of Candida infections has been shown. It has been recommended that in patients who are considered to be at increased risk, an antimicrobial agent such as povidone-iodine ointment be used at the insertion site of central venous catheters placed for the administration of parenteral nutrition. However, routine use of ointments is not recommended.

**CDC Guideline (1996)**
Do not routinely apply antimicrobial ointment to central venous catheter insertion sites.
Dressings

The ideal frequency of dressing changes and the type of dressing to use has not been established. Current recommendations by the Centers for Disease Control (1996) did not include a recommendation as to the frequency of dressing change. The types of dressings used for CVCs include gauze and tape and transparent semi-permeable membrane (TSM) dressings. With all types of dressings, it is preferable to change the dressing:

- In conjunction with any tubing change
- When it becomes damp, loosened, or soiled

**CDC Guideline (1996)**

- Replace catheter site dressings when the device is replaced, when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary
- No recommendation for the frequency of routine replacement of dressings used on central catheter sites

The traditional gauze and tape dressings have been used for years. Adhesive material should be applied over the entire gauze surface to ensure that the dressing is closed and intact. These dressings may be preferred for a diaphoretic patients or those with fragile or inflamed skin. Unfortunately, there is no way to observe the site without manipulating the dressing.

Transparent semi-permeable dressings are currently popular because they:

- Allow for continuous inspection of the site
- Adhere well to dry skin
- Provide protection against external moisture
- Are usually more comfortable
- May also assist in stabilizing and securing the catheter

The concern with these dressings is moisture retention occurring underneath the dressing. Moisture, of course, can lead to increased colonization of the site and increased risk of catheter-related infection.
Dressings (continued)

Research Riches
Another study by Maki found that, if the transparent dressing was left on for up to 5-7 days, there was more than a ten-fold increase in the density of cutaneous flora, which was then associated with a 50% increased risk of catheter-related infection.20

Newer dressing materials are available that allow for improved vapor transmission rate. Opsite IV 3000, for instance, is reported to move 3-8 times more moisture away from the site than other transparent dressings.

Research Riches
A recent study by Maki showed that, when this new dressing was used, there was no difference in infection or colonization rates when compared to gauze dressings.21

Other Considerations
Studies have shown that the use of special intravenous therapy teams consisting of trained nurses or technicians has been associated with substantially lower rates of catheter-related infection. However, even without a dedicated team, institutions can greatly reduce their rate of catheter-related sepsis by scrutinizing catheter care protocols and more intensively educating and training their clinicians.

Research Riches
In a study of cost effectiveness, Tomford and Hershey reported that such a team reduced the costs of complications of infusion therapy nearly ten-fold.22

Current trends in healthcare may also influence the infection rate associated with CVCs. Downsizing can result in inexperienced or insufficient personnel, and such trends maybe associated with increasing infection rates. Conversely, education and experience with the insertion and use of CVCs may reduce or prevent infections.
**CDC Guideline (1966)**

Conduct ongoing education and training of health care workers regarding indications for the use of and procedures for the insertion and maintenance of intravascular devices and appropriate infection control measures to prevent intravascular device-related infections. Audiovisuals can serve as a useful adjunct to standard educational effects.

**Clinical Considerations: Dressing Change**

**RECOMMENDED EQUIPMENT**
- Sterile gloves
- Mask
- Sterile drape
- Sterile gauze sponges and/or transparent dressings
- Sterile applicators
- Non-allergenic tape
- Solutions, ointments

**CLINICIAN RESPONSIBILITIES**
- Observe strict aseptic technique; change gloves between removal of old dressing and application of new one
- Position patient with head turned away from the dressing site or have patient wear a mask
- Remove old dressing and dispose of materials appropriately
- **Inspect site** for unusual warmth, erythema, edema, drainage, tenderness or pain
- Drape catheter insertion site
- Cleanse area, working in a circular path from the catheter to the periphery. Include the area under the hub
- Apply ointment, if appropriate. **Check for patient allergies.**
- Dress site with appropriate dressing material. **Dressing should be occlusive**
- Indicate date, time, and initial the dressing
- Chart procedure, site inspection, and any complications in the nursing/progress notes
Needlestick Injury

It is estimated that 600,000 to 1,000,000 workers are stuck by needles each year. In a one-year study conducted in 1994\(^{23}\), 24% of the healthcare workers who drew blood were stuck by a needle. Over 1,000 healthcare workers contract a serious infection from needlestick injuries annually. The lab work and treatment of workers injured by needle stick cost $600 - $1,000 per incident. This does not include the cost of loss of work and treatment from complications.

Of all the bloodborne diseases transmitted by used needles, the HIV virus has the most notorious reputation. However, as dreaded as the HIV virus can be, there are up to 20 other bloodborne diseases that can be transmitted to healthcare workers as a result of exposure to blood on the job. Of these, the diseases that pose the most serious threat to healthcare workers are Hepatitis B and Hepatitis C. Experts now estimate that more healthcare workers will eventually die due to complications from occupational exposure to Hepatitis C than from occupational exposure to HIV.

<table>
<thead>
<tr>
<th></th>
<th>HEPATITIS B</th>
<th>HEPATITIS C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of infections which result in chronic (long-term) infection.</td>
<td>Less than 10%</td>
<td>More than 85% (70% of all infections lead to chronic liver disease).</td>
</tr>
<tr>
<td>Number of people in U.S. with chronic infection.</td>
<td>1 to 1.25 million</td>
<td>3.9 million</td>
</tr>
<tr>
<td>This infection is transmitted to others in the following ways.</td>
<td>Contact with infected blood. Sexual contact. Perinatal (mother to child).</td>
<td>Contact with infected blood (transmission via sexual contact and perinatally occurs but is much less frequent).</td>
</tr>
<tr>
<td>Vaccine</td>
<td>There is an effective vaccine that can keep you from getting this disease.</td>
<td>THERE IS NO VACCINE.</td>
</tr>
<tr>
<td>Cure</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Treatment</td>
<td>Treatment with Interferon alpha produces a positive response in 35% of cases. Some people with HBV should not receive this treatment.</td>
<td>Interferon alpha, taken for one year, can help 15 to 25% of patients. A new combination drug therapy has reduced viral levels in 46% of cases.</td>
</tr>
</tbody>
</table>
Needlestick Injury  (continued)

<table>
<thead>
<tr>
<th>VIRUS</th>
<th>CHANCE OF INFECTION IF EXPOSED</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV</td>
<td>Very Low – there is a 0.3% (1 in 333) chance of being infected.</td>
</tr>
<tr>
<td>Hepatitis C (HCV)</td>
<td>Higher – there is a 5% (1 in 20) chance of being infected.</td>
</tr>
<tr>
<td>Hepatitis B (HBV)</td>
<td>Highest – there is a 6 to 30% (between 1 in 16 and 1 in 3) chance of being infected.</td>
</tr>
</tbody>
</table>


Safe Needles/Needleless Systems

Federally funded research has shown that most needlestick injuries can be prevented by switching to needleless IV connectors and using devices with incorporated safety features. In 1992, the FDA published a “Needleless Systems” safety alert warning about the risk of needlestick injuries from the use of hypodermic needles as a connection between two pieces of IV equipment. This alert was based on research that demonstrated that secondary IV tubing with connector needles was associated with the highest risk of needlestick injury.

**EXAMPLE OF SAFE NEEDLE**

This is an example of an “active” safety mechanism, requiring the healthcare worker to pull the sheath over the needle after use.

![Diagram of a safe needle showing the sheath being pulled over the needle after use.](image-url)
EXAMPLE OF NEEDLELESS SYSTEM

Timely Tip
Several states have mandated the use of safe needles and needleless systems to reduce the risks of sharps injury and resultant transmission of blood borne diseases.

With the advent of needleless systems, it is now most common for each lumen to be capped off with an injection cap. These caps need not be removed to allow the withdrawal of blood. This allows for a completely closed system, decreasing the chance of infection. Additionally, the use of stopcocks can also increase the risk of infection secondary to manipulation; however, the use of injection caps keeps the system closed. The needleless factor also contributes to patient and clinician safety.

Technical Tip
Today it is estimated by the FDA that more than 50% of all hospitals use needleless IV connection systems.
Blood Sampling

Blood sampling for various laboratory tests can be accomplished through central venous catheters. Generally, this procedure involves catheters with multiple lumens, but could also apply to single-lumen devices. When using the triple-lumen CVC, blood withdrawal may be done via the designated lumen, usually the proximal or distal lumen. The designation of these two lumens is arbitrary but is a result of the middle lumen usually being reserved for TPN administration. If the patient is not receiving TPN, any lumen will suffice.

Any laboratory test that does not require arterial blood can usually be drawn through the CVC. These tests may include:

- Chemistries
- Hematology studies
- Blood levels of drugs
- Coagulation studies
- Blood culture
- Cardiac enzymes

Blood Conservation

Studies have shown that patients in ICUs with an arterial line in place had a mean blood volume of 944 mL withdrawn and were phlebotomized a mean of 4 times daily during their ICU stay. This amount does not account for withdrawal and discard of flush solution mixed with blood; i.e., “clearing” volume. Additionally, this blood loss associated with diagnostic phlebotomy is superimposed on blood loss from other causes, such as gastrointestinal hemorrhage or surgery.

It is no wonder the terms iatrogenic or nosocomial anemia have appeared. Blood loss from phlebotomy alone can make a big impact on ICU patients, especially critically ill pediatric and neonatal patients, and certain adult patients with chronic renal failure, and those whose religious beliefs do not permit blood transfusions.

Draw Methods

There are three methods to obtain blood from a central line; direct, indirect or through a blood conservation device. Vacutainer devices can be connected directly to the injection cap attached to the appropriate lumen of the CVC. The vacuum within the collection tube draws out precisely the amount of blood needed for the specific laboratory test.
Draw Methods (continued)

When using this system, the **initial blood tube container drawn will represent the discard**. It is necessary to use an appropriately colored blood tube that corresponds to the amount of discard fluid desired.

In the **indirect** method, the syringe is inserted into the injection cap, and the appropriate volume of fluid is drawn and discarded. Then the volume of blood necessary for the particular laboratory test is withdrawn and then transferred into the blood collection tube. Although this procedure involves an extra step, it is often necessary to employ this method as the amount of suction generated in withdrawing the blood sample is controlled by the clinician.
Blood Sampling (continued)

When using a blood conservation device, the discard amount is withdrawn into a closed system and then reinfused following blood collection. (Although this line may attach directly through a luer lock to the central venous catheter, the system remains closed and is needleless.)

**Research Riches**

Studies have shown that results do not differ as a function of the method used to collect the sample if the samples are collected appropriately.\(^\text{25}\)

**Discard Volume**

A certain amount of blood is discarded prior to blood sampling (the discard volume) to avoid contamination of laboratory samples with heparin or saline. The amount of blood drawn back to clear the line is dependent on several factors, including:

- Tubing size and length
- Amount of heparin in the line
- Line from which blood is to be drawn
- Type of study to be performed

This volume is often expressed as multiples of the dead space within the catheter to be utilized for the blood draw. This is a function of the volume contained in the catheter from the tip of the catheter to the port from which the sample is to be drawn. Anywhere from **two to ten times** the dead space have been advocated. Some clinicians merely recommend a discard volume of **5-10 mL** with smaller waste volumes in neonatal and pediatric patients. However, hospital policies and procedures generally dictate the dead space specific to a particular institution.
Discard Volume (continued)

Sample of CVC Catheter Lumen Volumes (mL)

<table>
<thead>
<tr>
<th></th>
<th>16cm</th>
<th>20cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7F Double Lumen</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal</td>
<td>0.59</td>
<td>0.62</td>
</tr>
<tr>
<td>Distal</td>
<td>0.57</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>7F Triple Lumen</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal</td>
<td>0.47</td>
<td>0.52</td>
</tr>
<tr>
<td>Medial</td>
<td>0.45</td>
<td>0.47</td>
</tr>
<tr>
<td>Distal</td>
<td>0.56</td>
<td>0.60</td>
</tr>
<tr>
<td><strong>8.5F Double Lumen</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal</td>
<td>0.71</td>
<td>0.78</td>
</tr>
<tr>
<td>Distal</td>
<td>0.73</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>8.5F Quad Lumen</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal</td>
<td>0.31</td>
<td>0.39</td>
</tr>
<tr>
<td>Medial 1</td>
<td>0.29</td>
<td>0.36</td>
</tr>
<tr>
<td>Medial 2</td>
<td>0.30</td>
<td>0.38</td>
</tr>
<tr>
<td>Distal</td>
<td>0.65</td>
<td>0.88</td>
</tr>
</tbody>
</table>

**Practical Point**

An alternative to drawing a waste is to flush the catheter with 0.9% sodium chloride and then aspirate/flush back and forth multiple times to clear the catheter.

Chemistry Studies

Errors in potassium concentration may be related to the draw procedure. Blood cells may be damaged (hemolysis) during the procedure by:

- Drawing too fast
- Drawing through too small a lumen
- Excessive turbulence during the transfer procedure
Chemistry Studies (continued)

**Practical Point**

Always hold the blood sample level with the vacutainer during transfer of blood, and never push blood into collection device.

Additionally, errors in potassium measurements have been identified in specimens obtained from newly inserted central catheters, secondary to the presence of benzalkonium salts and the sensitivity of certain analyzers to them.\(^{26}\)

Accurate determination of sodium or glucose concentrations might be of concern, since 0.9% sodium chloride is often used to flush catheters, and IV fluids usually contain glucose. However, studies have shown that accurate results can be obtained if the dead space plus two milliliters is withdrawn as the discard volume.\(^{27}\)

**Practical Point**

It is interesting to note that, in spite of CDC guidelines, heparin mixed in dextrose solution is sometimes used to keep intravascular lines patent. In this instance, special care would need to be exercised. Even venous blood samples drawn via venipuncture from an extremity infused with D5W are not reliable, even when they are drawn from below the site of entry or even from a site remote from the glucose infusion.\(^{28}\)

**Hematology Studies**

These studies usually include determination of hemoglobin, hematocrit and white blood cell count. If the laboratory specimen were to contain flush fluid, the hematocrit determination could be falsely low due to the dilutional effect. The hemoglobin and white cell counts would be unaffected.

**Blood Cultures**

Blood cultures can be drawn from central lines. There is always the concern that any culture drawn from an indwelling intravascular catheter might show contamination that is related to the device rather than the patient. Of course, in some cases that is precisely the point. Generally, however, blood cultures are ordered in a series, each drawn from separate sites.
Blood Cultures

Research Riches
Most studies comparing the results of blood cultures drawn from arterial and central venous lines versus direct venipuncture found no significant differences. One study found a 93.5% incidence of identical results in 92 blood cultures simultaneously drawn from central venous pressure catheters and venipunctures.29

CDC Guideline (1996)
No recommendation for obtaining blood samples for cultures through central venous or central arterial lines.

Coagulation Studies
Perhaps the one type of laboratory test that would be most seriously affected by heparin flush fluid incorporated into the sample would be coagulation studies. Some hospitals might require all coagulation studies to be done by venipuncture to eliminate such concern.

Research Riches
However, studies have found no significant differences between samples obtained from arterial catheters and those obtained from venipuncture. Studies show reliable results on activated clotting time (ACT), prothrombin time (PT), activated partial thromboplastin time (aPTT), and thrombin time (TT) after sufficient discard volumes have been used.30

Research Riches
Confidence that six times the dead space volume is adequate for discard in the nonsystemically heparinized adult patient is supported in published literature. Results of two studies on heparinized patients indicated that this discard volume may be adequate for this population as well, but due to small sample size and exclusive use of the femoral site in these studies, further research is indicated. These results should not be generalized to systematically heparinized patients, pediatric patients, or other types of heparized lines such as pulmonary artery, central venous or Hickman catheters.31
Coagulation Studies (continued)

**Practical Point**

A practical approach is to draw all other laboratory samples first, saving the coagulation studies for last.

If laboratory values obtained from central venous catheters are markedly different in a previously stable patient, the test results should always be repeated before treating the patient.

There are not a lot of studies relating directly to drawing blood from central venous lines. Generally, the gold standard is direct venipuncture. Many studies discussed here relate to arterial lines as the source of blood that is compared to the venipuncture sample. However, central venous catheters have some similarities, especially in terms of flush solution to keep the line patent. Therefore, the assumption is that, if it can be declared reliable with arterial line draws, then it can also be accurate with CVC draws. Whenever possible, studies relating directly to central venous draws are discussed.

Clinical Considerations: Blood Sampling

**RECOMMENDED EQUIPMENT**

- Syringes/Vacutainers
- Heparin flush syringe with needleless cannula
- Sterile gloves
- Blood collection tubes
- Antiseptic swabs

**CLINICAL RESPONSIBILITIES**

- Review orders and check with the Laboratory if any concerns
- Inform patient of what procedure will entail and answer questions
- Use aseptic technique and meticulous handwashing
- Avoid opening the system as much as possible
- Utilize safety precautions such as needleless access
- Utilize strategies to minimize blood loss
Coagulation Studies (continued)

- Consider lumen choice based on drugs/fluids being infused
  Consider turning off infusions for 2-3 minutes, if appropriate
- Follow hospital policy and procedure as to appropriate discard volumes
- Ascertain that correct volume of blood is placed in the appropriate lab collection container

**Practical Point**

The volume of blood cultured is critical to maximize the yield of cultures. In adults, obtaining at least 20 mL, but ideally 30 mL, per drawing, with each specimen containing 10-15 mL, is recommended. 32

- Flush lumen after sample withdrawn
- Appropriately label specimen and send to laboratory
- Evaluate laboratory results and communicate them to clinician
- Go to resource personnel in event of technique-related questions
### Coagulation Studies (continued)

**Normal Reference Ranges for Laboratory Blood Tests**

<table>
<thead>
<tr>
<th>BLOOD CHEMISTRY STUDIES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium (Na)</td>
<td>136-145 mEq/L</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>3.5-5.0 mEq/L</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>98-106 mEq/L</td>
</tr>
<tr>
<td>Carbon dioxide (CO2)</td>
<td>21-30 mEq/L</td>
</tr>
<tr>
<td>Glucose (BS)</td>
<td>75-115 mg/dL</td>
</tr>
<tr>
<td>Blood Urea Nitrogen (BUN)</td>
<td>10-20 mg/dL</td>
</tr>
<tr>
<td>Creatinine</td>
<td>&lt;1.5 mg/dL</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>8.5-10.5 mEq/L</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>1.3-2.1 mEq/L</td>
</tr>
<tr>
<td>Osmolality</td>
<td>275-295 mOsm/kg</td>
</tr>
<tr>
<td>Bilirubin (direct)</td>
<td>0-0.3 mg/dL</td>
</tr>
<tr>
<td>Bilirubin (indirect)</td>
<td>0.2-0.7 mg/dL</td>
</tr>
<tr>
<td>Bilirubin (total)</td>
<td>0.2-1.0 mg/dL</td>
</tr>
<tr>
<td>Amalyse</td>
<td>25-125 U/L</td>
</tr>
<tr>
<td>Lipase</td>
<td>23-208 U/L</td>
</tr>
<tr>
<td>Anion Gap</td>
<td>8-16 mEq/L</td>
</tr>
<tr>
<td>Lactate</td>
<td>0.5-2.2 mEq/L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HEMATOLOGY STUDIES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Blood Cells (RBC)</td>
<td>4.25-5.5 x 10^6/µL (males) 3.6-5.0 x 10^6/µL (females)</td>
</tr>
<tr>
<td>White Blood Cells (WBC)</td>
<td>5-10 x 10^3/µL</td>
</tr>
<tr>
<td>Hemoglobin (Hgb)</td>
<td>13.5-17.5 g/dL (males) 12-16 g/dL (females)</td>
</tr>
<tr>
<td>Hematocrit (Hct)</td>
<td>40-54% (males) 37-47% (female)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COAGULATION STUDIES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Platelets</td>
<td>150-350 x 10^3/µμL</td>
</tr>
<tr>
<td>Prothrombin Time (PT)</td>
<td>10-14 sec</td>
</tr>
<tr>
<td>Plasma Thrombin Time (PTT)</td>
<td>30-45 sec</td>
</tr>
<tr>
<td>Activated Partial Thromboplastin Time (aPPT)</td>
<td>16-25 sec</td>
</tr>
<tr>
<td>Activated Clotting Time (ACT)</td>
<td>92-128 sec</td>
</tr>
</tbody>
</table>

*Normal value ranges depend upon specific laboratory determinations.*
Flush (Intermittent)

Although current practice mandates a flush procedure to maintain patency and prevent complications, the type, concentration, and volume of the solution vary widely from institution to institution and sometimes from unit to unit within the same institution.

Positive Pressure Flushing

Regardless of the amount and frequency of flush used, it is important to use a positive pressure flushing technique. A proper positive pressure flushing technique creates positive pressure within the lumen of the catheter and is thought to minimize reflux of blood into the tip of the catheter, and thus prevent clotting. This flush can best be performed by closing the catheter or extension clamp while flushing before the syringe completely empties. Another way to accomplish this would be to maintain pressure on the syringe plunger while withdrawing the syringe from the injection cap.

Consideration must also be given to the syringe size used to flush. The smaller the syringe size, the greater the pressure generated. Catheters are designed to withstand various infusion pressures; however, infusion pressures should never exceed 25-40 pounds per square inch (psi). Smaller-sized syringes will generate pressures in excess of this amount and may cause damage to catheters, especially if an obstruction is present. A 10mL syringe is advocated by many for use with CVCs.

Saline vs. Heparin

The anticoagulant properties of heparin have led clinicians to use heparin flushes to fill the lumens of central venous catheters locked between uses in an attempt to prevent thrombus formation and to prolong the duration of catheter patency. The efficacy of this practice is unproven.

There is a large amount of research indicating that peripheral intravenous catheters may be kept patent with intermittent saline flushes. Can the same be said for central venous lines? Much of the literature on CVCs is hard to interpret, because some long-term CVCs have been maintained with weekly saline flushes. However, these catheters do not see anywhere near the use involved in the care of critically ill patients.
Saline vs. Heparin (continued)

There is some literature dealing with arterial and pulmonary artery line patency. Most of the literature supports the use of heparinized flush solutions delivered continuously (on average, 3-5mL/hour) under 300 mmHg pressure. But what about the frequent but intermittently utilized CVCs? So far there are no clear-cut answers.

Research Riches
Conclusions of the AACN Thunder Project are probably applicable to CVCs: “....heparin does significantly affect patency of arterial pressure lines over time. However, lines can be kept patent without heparin, and other factors also significantly affect patency of arterial monitoring lines. Furthermore, the flush solution does not guarantee patency of the line.”33

Research Riches
Recent in vitro studies suggest that the growth of CoNS on catheters may be enhanced in the presence of heparin.34

Concentration
Various concentrations of heparinized saline from 5 to 1,000 USP units/ml are commonly used to flush CVCs. A questionnaire was distributed to a sample of persons attending the annual conference of the National Association of Vascular Access Networks in 1992. Heparin flushes were still used by 97% to maintain patency. The most commonly used concentration of heparin to maintain non-infusing CVCs was 100 units/mL. The Intravenous Nursing Standards recommends that the lowest possible concentration of heparin be used.

Research Riches
Stern et al hypothesized that the daily amount of heparinized saline solution injected via a heparin lock was 20 ml or approximately 2 ml of 1,000 U/ml heparin sodium – a total of 2,000 U/day.35
Saline vs. Heparin (continued)

Clinical Concern
Administration of low-dose heparinized saline solution has been associated with hypersensitivity reaction, transient increases in activated partial thromboplastin time, delayed fibrinolysis with platelet aggregation, and thrombocytopenia. Drug interactions occur with diazepam, meperidine, promethazine, hydroxyzine, tetracycline, penicillin G, methicillin, erythromycin gluceptate, gentamicin, and dacarbazine. At least one case of iatrogenic hemorrhage has resulted from the flushing of multiple catheters.36

Flush Volume
It has been accepted that the volume of the heparinized saline flush be equal to two times the volume capacity of the cannula. (See previous for catheter lumen volumes.) Typical flush volumes range from 1-5 mL.

Clinical Considerations: Flushing

RECOMMENDED EQUIPMENT
- Antiseptic swabs
- 10mL syringe with needleless cannula
- Heparin flush solution (concentration per hospital policy)

CLINICAL RESPONSIBILITIES
■ Cleanse injection site with approved antiseptic solution
■ Use a 10 mL syringe
■ Maintain positive pressure during flushing
■ Monitor coagulation parameters
Infusion Therapy

One of the major indications for the percutaneous placement of a short-term polyurethane multi-lumen central venous catheter is to allow for the delivery of various therapies through a single venipuncture. Solutions that are infused through multi-lumen catheters in the critical care area may include maintenance or replacement fluids, medications, blood products or total parenteral nutrition (TPN).

Fluid Administration

With appropriate catheter tip placement within the central circulation, large volumes of fluid can be administered and diluted rapidly. Most fluids can be administered safely. However, solutions/medications containing high concentrations of alcohol should not be infused through polyurethane catheters due to alcohol’s weakening effect on the material.

### CONCENTRATIONS IN FREQUENTLY USED INTRAVENOUS SOLUTIONS (MEQ/L)

<table>
<thead>
<tr>
<th>FLUID</th>
<th>GLUCOSE</th>
<th>NA⁺</th>
<th>K⁺</th>
<th>CL⁻</th>
<th>MOSM/L</th>
<th>KCAL/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>50g</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>252</td>
<td>170</td>
</tr>
<tr>
<td>D10W</td>
<td>100g</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>505</td>
<td>340</td>
</tr>
<tr>
<td>D50W</td>
<td>500g</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2520</td>
<td>1700</td>
</tr>
<tr>
<td>1/2 NS</td>
<td>0</td>
<td>77</td>
<td>0</td>
<td>77</td>
<td>154</td>
<td>0</td>
</tr>
<tr>
<td>(0.45% NS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>0</td>
<td>154</td>
<td>0</td>
<td>154</td>
<td>308</td>
<td>0</td>
</tr>
<tr>
<td>(0.9% NS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D51/4NS</td>
<td>50g</td>
<td>38</td>
<td>0</td>
<td>38</td>
<td>329</td>
<td>170</td>
</tr>
<tr>
<td>D5 1/2NS</td>
<td>50g</td>
<td>77</td>
<td>0</td>
<td>77</td>
<td>406</td>
<td>170</td>
</tr>
<tr>
<td>D5 NS</td>
<td>50g</td>
<td>154</td>
<td>0</td>
<td>154</td>
<td>560</td>
<td>170</td>
</tr>
<tr>
<td>LR</td>
<td>0</td>
<td>130</td>
<td>4</td>
<td>110</td>
<td>272</td>
<td>10</td>
</tr>
</tbody>
</table>

IV Delivery System

Many policies have advocated routinely replacing the entire infusion delivery system at certain intervals to reduce the risk of sepsis from extrinsically contaminated fluid. If an infusion runs continuously for an extended period, the cumulative risk of contamination increases, and there is increased risk that the contaminants could grow to dangerously high concentrations, resulting in septicemia.
However, contaminated infusion is not a common cause of most catheter-related bacteremias. Contaminated infusate can result from intrinsic (introduced during its manufacture) or extrinsic (introduced during its preparation or administration in the hospital) contamination. Microorganisms can be introduced extrinsically into the fluid being infused from entry points into the administration set (during injections into the line or aspiration of blood specimens from the intravascular device through the line) or at the junction between the administration set and the catheter hub. However, the majority of introduced contaminants are rapidly cleared from running infusion by continuous flow.

Most studies indicate that intravenous delivery systems do not need to be replaced more frequently than every 72 hours.

**CDC Guideline (1996)**
- Replace extension tubing when the vascular device is replaced
- Replace IV tubing, including piggyback tubing and stopcocks, no more frequently than at 72-hour intervals, unless clinically indicated
- No recommendation for the hang time of IV fluids, including non-lipid containing parenteral nutrition fluids

**In-Line Filters**

The use of filters continues to be advocated as a means of reducing the hazard of contaminated infusate. However, filters must be changed at periodic intervals and can become blocked, leading to added manipulations of the system, and, paradoxically, greater potential for infection.

Additionally, the use of filters:
- May permit the passage of endotoxin
- Are expensive
- May not be justified as a control method for prevention of rare sporadic septicemias deriving from extrinsic contamination of infusate
In-Line Filters (continued)

**CDC Guideline (1996)**

Do not use filters routinely for infection control purposes.

### Stopcocks

Stopcocks used for injection of medications, administration of IV infusions, or collection of blood samples, may represent a source of entry for microorganisms. Although stopcock contamination is **common** (45-50%), the relative contribution of stopcock contamination to intravascular catheter or IV fluid contamination is **unclear**. Few studies have been able to demonstrate that the organism colonizing the stopcock is the same one responsible for catheter-related infection.

Even if stopcocks are used, **injection caps** may be placed on each port to keep the system as closed as possible.

**CDC Guideline (1996)**

- Clean injection ports with 70% alcohol or povidone-iodine before accessing the system
- No recommendation for use, maintenance, or frequency of replacement of needleless IV devices

### Piggyback Systems

Piggyback systems may be used as an alternative to stopcocks. They pose a risk for contamination of the intravascular fluid if the needleless cannula entering the injection port is partially exposed to air and/or subject to repeated connections and disconnections as might occur with intermittent administration of antibiotics. The use of a **closed piggyback system** in which the piggyback line is never detached from the primary line would seem to decrease the chance of infection.

**Research Riches**

Modified piggyback systems appear to prevent contamination at these sites and reduce the incidence of catheter-related BSI six-fold when compared with conventional stopcock and piggyback systems. 37
Practical Point

One piggyback line can be used for multiple intermittent infusions, even if the medications are incompatible, as long as all medications to be piggybacked are compatible with the primary solution. When one medication is finished, the line is back-flushed to fill the short line with primary solution. Another partial-fill can then be spiked and administered.

CDC Guideline (1996)

No recommendation for frequency of replacement IV tubing used for intermittent infusions.

Medication Administration

Drug administration is an important therapeutic intervention in the care of the critically ill patient and is, therefore, a concern for the critical care clinician. As a basic principle, only one drug should be added to an infusion fluid, and no drugs should be co-administered in the same line. Hence, the rationale for multi-lumen catheters in the critically ill population.

However, these patients often require several intravenous medications administered simultaneously, in excess of the amount of lumens available. This may be accomplished via three-way stopcocks, multiple y-sites, or manifolds attached to multi-lumen catheters. Therefore, more than one medication may be administered through a portion of a single line.

When using such devices, the clinician must be aware of several factors in order to safely administer drugs to the critically ill patient. Are the drugs compatible with each other? Compatible with the catheter material? Will the desired effect be achieved? There are various charts available that attempt to delineated drug compatibilities/incompatibilities for the clinician; however, these are considered as guidelines only. It is always recommended that instructions provided by intravenous drug suppliers and/or device manufacturers be read carefully.
Medication Administration (continued)

Drug Incompatibility

A drug incompatibility is defined as failure of a drug or drug mixture to combine with another drug, diluent, or infusion device system in an expected or desired manner. Drugs are assumed to be compatible when mixed if there is no sign of physical or chemical incompatibility.

Physical incompatibility – combination of two or more drugs resulting in a change in the appearance of the solution (precipitation, color change, or cloudiness)

Chemical incompatibility – significant drug degradation (usually a > 10% loss of potency) occurring with or without a change in the appearance of the solution

(Physical compatibility does not imply chemical compatibility)

Due to the larger vessel size and flow velocity surrounding the catheter lumen exit sites in the central venous system, simultaneous administration of incompatible medications has been practiced. However, few studies have evaluated the safety and efficacy of this in clinical practice.

Grillo et al. looked at the chemical compatibility of inotropic and vasoactive agents delivered via a multiple line infusion system. They studied three different triple-drug admixtures diluted with either 5% dextrose in water or 0.9% sodium chloride solution. The triple drug admixtures were combinations of dobutamine, dopamine, norepinephrine, nitroglycerin, and sodium nitroprusside. All triple-drug admixtures were chemically stable when placed in single containers. Dobutamine, norepinephrine, and sodium nitroprusside showed chemical stability when delivered via a multiple-line infusion system. Therefore, these drugs should be able to be administered through the same line in a multi-lumen central venous catheter.

Other Considerations

Although infusion of incompatible medications through various lumens is possible through multi-lumen catheters, studies have shown that blood volume and the configuration of the lumen exit sites at the distal end of the catheter may be important factors to consider. One recent study attempted to evaluate the simultaneous administration of incompatible medications by using an in vitro venous flow model system designed to mimic an in vivo clinical situation.
The study looked at the physiochemical phenomena that occur when two known incompatible drugs, phenytoin and TPN, were simultaneously administered through a multi-lumen CVC. This study showed that the design of the catheter might have an impact on precipitate formation. Catheters designed with adjacent exit sites (ports) at the tip of the double-lumen catheter appeared to permit interaction of the two infusing incompatible drugs. Staggered orifices (exit ports), on the other hand, reduced this interaction. This study concluded that the clinical significance of this phenomenon has yet to be assessed.

Nitroglycerin Administration

Consideration must be given to the effects that certain medications have upon the catheter as well as on other simultaneous infusions. The problem of the adsorption of nitroglycerin onto some catheter materials, namely polyvinyl chloride, has been reported in the literature. Adsorption is the adhesion of a gas or liquid to the surface of a solid; i.e., the medication is “leached” out into the tubing or catheter material instead of being delivered to the patient. Polyurethane, the material used to make most central venous catheters, does not contribute to leaching of this drug.

This effect of adsorption is more prominent if agents are administered in small quantities or at low concentrations and in the initial phase of administration. This is a particularly significant point to remember when starting a vasoactive drug that will be titrated. After this initial phase, adsorption continues, but at a lower rate. In consequence, the dose administered to the patient may increase with time, although the infusion rate is kept constant. This may require adjustments in the rate of infusion.

The clinical significance of the adsorption is controversial, however, since the drug is often titrated to effect. Nitroglycerin is usually mixed in glass bottles to minimize the leaching effect of the container. Some institutions use non-PVC tubing when administering nitroglycerin; others do not. Some “saturate” the tubing initially by flushing it rapidly with the medication to be infused. Follow the institution’s policy when it comes to nitroglycerin administration.
**Clinical Consideration**

Low dose dopamine (for renal perfusion, for instance) may be administered through a peripheral line in some cases. However, titratable doses for vasoactive purposes need to go through a central line for several reasons. The dosages are greater and the action of the drug needs to be central, rather than local. Also, local vasoconstriction from higher dosages of dopamine might limit the amount of drug that could get into the central circulation – as well as potentially injure the surrounding tissues.

**Blood Administration**

Another indication for the placement of a central venous catheter is for frequent administration of blood or blood products. According to the Core Curriculum for Critical Care Nursing by the American Association of Critical-Care Nurses, peripheral IV sites may be used for this purpose as long as at least a 20 gauge access (to prevent hemolysis) is used. However, central venous catheters, with their larger lumens and more stable access, may be preferable.

**CDC Guideline (1996)**

Replace tubing used to administer blood, blood products, or lipid emulsions within 24 hours of initiating the infusion.

**Administration of TPN**

Although enteral feeding is preferred, a substantial number of critically ill patients receive parenteral nutrition. The risk of bloodstream infection remains one of the most important complications associated with TPN therapy. This is due to the fact that dextrose, amino acids, or lipid emulsions are more likely than conventional IV fluids to support microbial growth.
Special precautions need to be taken with TPN. Experienced pharmacists use an aseptic technique when mixing solutions under a laminar flow hood. Total parenteral nutrition should ideally be delivered in a dedicated line that should be left unbroken in order to reduce the possibility of infection. No secondary (or piggyback) tubings, except lipids, are permitted into this line. Nearly all septicemias linked to contaminated infusate have been gram-negative bacilli. However, microbial growth in most parenteral solutions, with the exception of lipid emulsion, is actually very limited.

Lipid emulsions, however, are particularly suited for growth of specific bacteria and yeasts, including *Candida* species. Microbial growth occurs as early as 6 hours, with clinically significant levels being reached within 24 hours.

**Nurses Notes**

Combined TPN solutions (3-in-1), which use glucose, amino acids, lipid emulsion, and additives in one multi-liter bag, do not appear to support greater microbial growth than non-lipid containing TPN fluids.

**Clinical Consideration**

TPN may be administered peripherally as long as the dextrose content is low enough not to irritate the vessel. However, peripheral TPN does not provide the nutritional benefit of central TPN solutions.

**CDC Guideline (1996)**

- Do not use single-lumen parenteral nutrition catheters for purposes other than hyperalimentation (e.g., administration of fluids, blood, or blood products)
- If a multi-lumen catheter is used to administer parenteral nutrition, designate one port for hyperalimentation. Do not use the designated hyperalimentation port for other purposes (e.g., administration of fluids, blood, or blood products)
Administration of TPN (continued)

- Complete infusions of lipid-containing parenteral nutrition fluids (e.g., 3-in-1 solutions) within 24 hours of hanging the fluid
- When lipid emulsions are given alone, complete the infusion within 12 hours of hanging the emulsion

Clinical Considerations: IV Administration

**RECOMMENDED EQUIPMENT**
- Volumetric infusion pump
- IV fluid and appropriate tubing

**CLINICAL RESPONSIBILITIES**
- Review orders
- Identify patient
- Dedicate one lumen for TPN administration
- Do not infuse solutions with a high concentration of alcohol through polyurethane catheters or tubing
- Flush after medication administration to deliver any residual portion of the dosage to the patient
- Do not push IV medications through lumen containing vasoactive drugs (since this may precipitate serious cardiovascular events)
- Consult compatibility tables or pharmacist when administering more than one drug through a lumen

*Practical Point*

If in doubt as to compatibility of an intermittent push medication, flush the intended line with a known compatible solution, follow push with similar flush.
- Observe tubing and IV solution for precipitation or any other signs of incompatibility
- Follow specific guidelines for blood administration
## Frequently Used Drugs in Critical Care

<table>
<thead>
<tr>
<th>DRUG</th>
<th>MECHANISM OF ACTION/EFFECTS</th>
<th>INDICATIONS</th>
<th>DOSAGE</th>
<th>PRECAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adenosine</strong></td>
<td><em>↓</em> sinus rate.</td>
<td>Conversion of supraventricular tachycardia to a regular sinus rhythm, including PSVT associated with accessory bypass tracts that involve the AV node. (as seen in WPW) that is refractory to vagal maneuvers.</td>
<td>Initial bolus = 6 mg rapid IV bolus over 1-3 seconds followed by a 20 ml saline flush. Wait 1-2 minutes. If no response observed, administer 12 mg (may repeat the 12 mg dose once in the 1-2 minutes). Due to extremely short half-life, start IV line as proximal to the heart as possible, such as the antecubital fossa. Onset: Seconds. Peak: Seconds. Duration: 10-12 seconds.</td>
<td>Side effects but transient and usually resolve spontaneously within 1-2 minutes – flushing, dyspnea, chest pain. Consider ↓ dose in patients on theophylline since methylxanthines prevent binding of adenosine at receptor sites. Consider ↓ dose in patients on dipyridamole (Persantine) because adenosine potentiates its effects. Relatively high incidence of recurrence of the tachycardia after 6 mg dose; 92% conversion to a sinus rhythm after 12 mg bolus.</td>
</tr>
<tr>
<td><strong>Trade Name:</strong></td>
<td><strong>Adenocard</strong></td>
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<tr>
<td><strong>Class:</strong></td>
<td><strong>Endogenous chemical, Antidysrhythmic</strong></td>
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<td></td>
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<tr>
<td><strong>Half-life is less than 5 seconds.</strong></td>
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</tbody>
</table>
| **Amrinone** | Potent inotropic effect.     | Severe CHF that has not responded to diuretics, vasodilators and conventional inotropic agents. | 0.75 mg/kg over 2-3 minutes followed by an infusion @ 5-15 µg/kg/min, titrated to effect. | ■ Incompatible with furosemide. ■ May exacerbate myocardial ischemia. ■ May worsen ventricular ectopy. ■ Should be administered via an infusion pump. ■ Hemodynamic monitoring is suggested for optimal use. |}
| **Trade Name:** | **Inocor** |                                                                                           |                                                                                                                                  |                                                                                                                                       |
| **Class:**   | **Non-adrenergic, non-ß-agonist** |                                                                                           |                                                                                                                                  |                                                                                                                                       |
### Administration of TPN (continued)

<table>
<thead>
<tr>
<th>DRUG</th>
<th>MECHANISM OF ACTION/EFFECTS</th>
<th>INDICATIONS</th>
<th>DOSAGE</th>
<th>PRECAUTIONS</th>
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<tbody>
<tr>
<td><strong>β-Adrenergic Blockers</strong></td>
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<tr>
<td>Atenolol (Tenormin)</td>
<td>↓ incidence of VF in post-MI patients who did not receive thrombolytic agents.</td>
<td>Atenolol: 5 mg IV over 5 min, may repeat in 10 min.</td>
<td>Should be avoided in: ■ bradycardia. ■ second or third-degree AV block. ■ hypotension. ■ overt CHF. ■ lung disease associated with bronchospasm.</td>
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<tr>
<td>Esmolol (Brevibloc)</td>
<td>↓ rate of discharge of sinus node.</td>
<td>Esmolol: 500 µg/kg over 1 minute (loading dose) followed by a maintenance infusion at 50 µg/kg/min over 4 minutes.</td>
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<tr>
<td>Metoprolol (Lopressor)</td>
<td>↓ myocardial contractility.</td>
<td>Metoprolol: 5 mg slow IV push at 5 min intervals to total of 15 mg.</td>
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<td></td>
</tr>
<tr>
<td>Propranolol (Inderal)</td>
<td>↓ incidence of VF in post-MI patients who did not receive thrombolytic agents.</td>
<td>Propranolol: Total dose of 0.1 mg/kg slow IV push divided into 3 equal doses at 2-3 intervals.</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bretylium Tosylate</th>
<th>Not a first-line antidysrhythmic.</th>
<th>Refractory VF/ pulseless VF: 5 mg/kg rapid IV bolus followed by defibrillation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade Name: Bretyloll</td>
<td>Initial sympathomimetic effects due to release of norepinephrine: ■ ↑ heart rate. ■ ↑ peripheral vasoconstriction. ■ ↓ blood pressure. ■ ↓ cardiac output.</td>
<td>If VF persists, ↓ dose to 10 mg/kg and repeat every 5 min to maximum dose 30-35 mg/kg. If conversion occurs to a perfusing rhythm after bolus therapy, initiate a continuous infusion at 1-2 mg/min.</td>
</tr>
<tr>
<td>Class: Venticular antidy- rhythmic, Adrenergic blocker</td>
<td>Subsequent sympatholytic response after 15-20 minutes (adrenergic block): ■ ↓ blood pressure ■ Suppresses, ventricular ectopy, ■ ↓ VF threshold.</td>
<td>To mix drip: 1 gram in 250 ml or 2 grams in 500 ml. Using a microdrip (60 gtts/ml) administration set: 1 mg/min = 15 gtts/min 2 mg/min = 30 gtts/min Persistently recurring VT (with a pulse): (IV infusion) 5-10 mg/kg diluted in 50 ml and infused over 8-10 min to avoid nausea/vomiting. If conversion occurs, initiate a continuous mg/min. infusion at 1-2</td>
</tr>
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</table>

Postural hypotension. Nausea/vomiting due to release of epinephrine and lidocaine. After defibrillation, epinephrine and lidocaine have failed to convert VF. Lidocaine has returned despite epinephrine and lidocaine. Lidocaine and procaainamide have failed to control VT associated with a pulse. Lidocaine and adenosine have failed to control wide-complex tachycardias.
<table>
<thead>
<tr>
<th>DRUG</th>
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<th>INDICATIONS</th>
<th>DOSAGE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>↑ myocardial contractile</td>
<td>Probably helpful (Class IIa) in:</td>
<td>2-4 mg/kg (usually 500 mg – 1 gram) with repeated as necessary at 10 minute intervals.</td>
<td>■ Bradycardia with rapid IV injection.</td>
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<tr>
<td>Chloride</td>
<td>function.</td>
<td>■ Hypokalemia.</td>
<td></td>
<td>■ Use with caution in digitalized patients.</td>
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<tr>
<td></td>
<td></td>
<td>■ Hyperkalemia.</td>
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<td>■ Precipitates with bicarb.</td>
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<tr>
<td></td>
<td></td>
<td>■ Hypocalcemia.</td>
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</tr>
<tr>
<td>Calcium</td>
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<td>■ Calcium channel blocker toxicity.</td>
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<td>May also be used to pretreat patients with PSVT prior to administration</td>
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<td></td>
<td></td>
<td>of verapamil.</td>
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<tr>
<td>Diltiazem</td>
<td>Slows conduction and</td>
<td>Multifocal atrial tachycardia, atrial fibrillation or atrial flutter with</td>
<td>0.25 mg/kg (20 mg) IV over 2 minutes followed 15 minutes later by 0.35 mg/kg (25 mg) IV over 2 minutes.</td>
<td>■ Produces less myocardial depression than verapamil.</td>
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<td>increases refractoriness in</td>
<td>a rapid ventricular response.</td>
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<td>■ Avoid or use with caution in left ventricular dysfunction.</td>
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<tr>
<td></td>
<td>the AV node.</td>
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<td>■ Common side effects include hypotension and flushing.</td>
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<tr>
<td>Dobutamine</td>
<td>β-adrenergic stimulator.</td>
<td>Refractory congestive heart failure (systolic BP &gt; 100 mm Hg with normal</td>
<td>2-20 µg/kg/min (usual dose 2.5-10 µg/kg/min). To prepare infusion:</td>
<td>■ Avoid in patients with AV block, sinus node dysfunction or severe cardiac failure.</td>
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<tr>
<td></td>
<td>Potent inotropic effect (↑</td>
<td>diastolic BP).</td>
<td>Mix 250 mg in 250 ml (1000 µg/ml) and titrated to desired response.</td>
<td>■ Do not administer to patients with WPW – may worsen dysrhythmia.</td>
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<td></td>
<td>myocardial contractility →</td>
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<td>■ Not effective in VT.</td>
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<td>↑ stroke volume → ↑ cardia</td>
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<td></td>
<td>c output).</td>
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<td></td>
<td>Less chronotropic effect</td>
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<tr>
<td></td>
<td>(heart rate).</td>
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<td></td>
<td>Stimulates β-2 receptors</td>
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<td>at doses &gt; 10 µg/kg/min →</td>
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<td></td>
<td>peripheral vasodilation →</td>
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<td></td>
<td>↑ systemic vascular</td>
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<td></td>
<td>resistance.</td>
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### Administration of TPN (continued)

<table>
<thead>
<tr>
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<th>DOSAGE</th>
<th>PRECAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dopamine</td>
<td>Precursor of epinephrine that has dopaminergic, α and β-adrenergic receptor stimulating actions.</td>
<td>Hypotension that occurs with symptomatic bradycardia.</td>
<td>Only administered by IV infusion, never as a bolus.</td>
<td>MAO inhibitors potentiate effects of dopamine.</td>
</tr>
</tbody>
</table>
|            | Low dose (1-5 μg/kg/min):  
|            | ■ Dopaminergic effect dilates renal and mesenteric vessels.  
|            | ■ May not ↓ heart rate or blood pressure at this dose range.                                                                                                                                                              | Hypotension that occurs after return of spontaneous circulation.                                | 5-20 μg/kg/min, titrated to desired effect.                                                                                                                                                    | May induce tachycardia necessitating ↓ dosage or discontinuation of infusion.                                                                 |
|            | 5-10 μg/kg/min:  
|            | ■ Predominant β-adrenergic stimulating properties → ↑ force of contraction, minimal ↑ in heart rate → ↑ cardiac output.                                                                                                       | Cardiogenic shock.                                                                             | To mix infusion: 400 mg dopamine in 250 ml (or 800 mg dopamine in 500 ml) → 1600 μg/ml concentration.                                                                                        | Extravasation may result in tissue sloughing or necrosis – monitor IV site closely.                                          |
|            | > 10-20 μg/kg/min:  
|            | ■ α effects dominate → renal, mesenteric, peripheral arterial and venous vasoconstriction → ↑ systemic vascular resistance and preload, ↓ heart rate.                                                                               |                                                                                                 |                                                                                          | Should not be administered with alkaline solutions – inactivates dopamine.                                                                                                      |
|            |                                                                                                                                                                                                                    |                                                                                                 |                                                                                          | Do not discontinue abruptly – taper gradually.                                                                                                                                                    |
|            |                                                                                                                                                                                                                    |                                                                                                 |                                                                                          | Should be infused via an infusion pump.                                                                                                                                                    |
|            |                                                                                                                                                                                                                    |                                                                                                 |                                                                                          | Should be infused via a central vein – if central venous access not possible, use a large peripheral vein (antecubital vein).                                                                 |
|            |                                                                                                                                                                                                                    |                                                                                                 |                                                                                          | Correct hypovolemia before administration of dopamine.                                                                                                                                       |
## Administration of TPN (continued)

<table>
<thead>
<tr>
<th>DRUG</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Epinephrine</strong>&lt;br&gt;Trade Name: Adrenalin&lt;br&gt;Class: Sympathomimetic, Natural Catecholamine</td>
<td>Produces beneficial effects in patients during cardiac arrest primarily because of its α-adrenergic stimulating properties. α-adrenergic effects: ↑ systemic vascular resistance (vasoconstriction) → ↑ diastolic pressure → ↓ myocardial and cerebral blood flow during CPR. β-adrenergic effects: ↑ heart rate (+ chronotropy) ↑ myocardial contractility (+ inotropy) Results in ↓ myocardial oxygen demand.</td>
<td>First agent in cardiac arrest: IV Bolus: ■ VF. ■ Pulseless VT. ■ Pulseless, electrical activity. ■ Asystole. Infusion: ■ VF. ■ Pulseless VT. ■ Vasopressor agent for patients with symptomatic bradycardia (not a firstline agent).</td>
<td>1 mg of 1:10,000 solution IV bolus every 3-5 min. Intermediate dose: 2-5 mg IV bolus every 3-5 min. Escalating dose: 1 mg, 3 mg, 5 mg IV bolus (3 min apart). High dose: 0.1 mg/kg IV bolus every 3-5 min. Epinephrine infusion: start at 1 µg/min and titrate to desired response (2-10 µg/min). To prepare infusion: mix 1 mg in 250 ml (4 µg/ml) or 1 mg in 500 ml (2 µg/ml). - Endotracheal dose 2-2 1/2 times IV dose (prepare 2-2 1/2 mg of epinephrine 1:1000 solution, add normal saline for total volume of 10 ml and administer).</td>
<td>Continuous IV infusions of epinephrine should be administered via a central vein to the ↓ risk of extravasation. Should not be administered in the same IV line as alkaline solutions – inactivates epinephrine. Epinephrine infusion should be administered via an infusion pump.</td>
</tr>
<tr>
<td><strong>Isoproterenol</strong>&lt;br&gt;Trade Name: Isuprel&lt;br&gt;Class: Sympathomimetic, Beta-Agonist, Synthetic Catecholamine</td>
<td>Pure β-adrenergic stimulator (β-1 and β-2). Potent chronotropic effect (heart rate) (primary effect). Inotropic effect (↑ force of contraction). ↓ cardiac output. ↓ myocardial O₂ consumption → ↓ myocardial ischemia. Vasodilation.</td>
<td>Class IIa (probably helpful) Refractory torsades de pointes (overdrives the ventricular rate – “chemical” overdrive pacing). Class IIb (possibly helpful) in low doses for symptomatic bradycardia (after atropine, pacing, dopamine and epinephrine). Class III (may be harmful) in higher doses for symptomatic bradycardia.</td>
<td>2-10 µg/min titrated to desired response (for bradycardia, usually titrated to a heart rate of 60 beats/minute). To mix drip: 1 mg in 250 ml (4 µg/ml).</td>
<td>If used for symptomatic bradycardia, should be used with extreme caution. Not indicated in patients with cardiac arrest or hypotension. Excessive tachycardia. Dysrhythmias. ↑ myocardial O₂ consumption.</td>
</tr>
</tbody>
</table>
# Administration of TPN (continued)

<table>
<thead>
<tr>
<th>DRUG</th>
<th>MECHANISM OF ACTION/EFFECTS</th>
<th>INDICATIONS</th>
<th>DOSAGE</th>
<th>PRECAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lidocaine Hydrochloride</strong></td>
<td>Suppresses ventricular ectopy. VF threshold.</td>
<td>Significant ventricular ectopy (runs of VT, “R on T” PVCs) seen in the setting of acute MI/ischemia.</td>
<td>VF/Pulseless VT: 1-1.5 mg/kg repeated in 3-5 min to maximum dose of 3 mg/kg. VF with pulse/Wide-complex tachycardia of uncertain origin, significant ventricular ectopy (PVCs): 1-1.5 mg/kg repeated every 5-10 min as needed with 0.5-0.75 mg/kg to total dose of 3 mg/kg.</td>
<td>Indications of toxicity are usually CNS related: Muscle twitching, Seizures, Slurred speech, Altered LOC, Respiratory arrest.</td>
</tr>
<tr>
<td><strong>Trade Name:</strong> Xylocaine</td>
<td>Decreases excitability in ischemic tissue.</td>
<td>VT/VF that persist after defibrillation and administration of epinephrine.</td>
<td>Only bolus therapy used in cardiac arrest. After return of pulse, continuous infusion (IV drip): after 1 mg/kg → drip 2 mg/kg after 1/1-2 mg/kg → drip 3 mg/kg after 2-3 mg/kg → drip 4 mg/kg</td>
<td>Because lidocaine is metabolized in the liver, reduce dose in: Decreased cardiac output (acute MI, CHF, shock), Elderly patients (&gt;70 years), Hepatic dysfunction.</td>
</tr>
<tr>
<td><strong>Class:</strong> Ventricular antidysrhythmic</td>
<td>Does not significantly affect myocardial contractility in therapeutic doses.</td>
<td>VT with a pulse. Wide-complex tachycardia of uncertain origin.</td>
<td>To mix drip: 1 gram in 250 ml or 2 grams in 500 ml. Using a microdrip (60 gtts/ml) administration set: 1 mg/min = 15 gtts/min 2 mg/min = 30 gtts/min 3 mg/min = 45 gtts/min 4 mg/min = 60 gtts/min</td>
<td>In these patients, the normal bolus dose should be administered first, followed by 1/2 the normal maintenance infusion.</td>
</tr>
<tr>
<td>****</td>
<td>Routine prophylactic use in uncomplicated MI or ischemia without PVCs is no longer recommended.</td>
<td>Routine prophylactic use in uncomplicated MI or ischemia without PVCs is no longer recommended.</td>
<td>Endotracheal dose 2-21/2; times IV dose diluted in 10 ml normal saline or distilled water.</td>
<td>Do not treat ventricular ectopy first if the heart rate is &lt; 60 beats/minute – treat the bradycardia.</td>
</tr>
<tr>
<td><strong>Endotracheal dose 2-21/2; times IV dose diluted in 10 ml normal saline or distilled water.</strong></td>
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<td></td>
<td></td>
<td>Lido she may be lethal in a bradycardia with a ventricular escape rhythm (second degree AV block, type II, third-degree (complete) AV block with a wide-QRS.)</td>
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</table>
## Administration of TPN (continued)

<table>
<thead>
<tr>
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</thead>
</table>
| **Magnesium Sulfate** | May ↓ early MI mortality. May ↓ incidence of dysrhythmias that often occur in survivors of MI. Mechanism of action not completely understood. May ↓ due to:  
  - Systemic vasodilation → ↓ myocardial oxygen demand.  
  - ↓ platelet aggregation.  
  - Coronary vasodilation.  
  - Improved myocardial metabolism.  
  - ↓ myocardial irritability.  
  - Protection against catecholamine induced myocardial necrosis. | Torsades de Pointes.  
  - Pulseless VT/VF: Acute MI with known or suspected hypomagnesemia. | Pulseless VT/VF: 1-2 grams IV (2-4 ml of 50% solution) diluted in 10 ml and administered over 1-2 minutes.  
  - Acute MI, Hypomagnesemia. Loading dose of 1-2 grams mixed in 50-100 ml of NS and administered over 5-60 minutes.  
  - Torsades de Pointes 1-2 grams IV (2-4 ml of 50% solution) diluted in 10 ml administered over 1-2 minutes followed by the same amount (mixed in 50-100 ml of NS) infused over 1 hour. | Magnesium deficiency is associated with cardiac dysrhythmias, symptoms of cardiac insufficiency and sudden cardiac death.  
  - Signs/symptoms of magnesium overdose include ↓ respiratory rate, hypotension, hyporeflexia.  
  - Calcium chloride should be on hand for IV administration if signs of magnesium overdose develop. |
| **Norepinephrine** | Naturally occurring potent vasoconstrictor (α-receptor stimulating agent) and inotropic (β-1 receptor stimulator) agent.  
 90% α, 10% β. α activity usually dominant. Usually causes renal and mesenteric vasoconstriction. | Cardiogenic shock.  
  - Severe hypotension (systolic BP < 70). | 0.5-30 µg/min titrated to effect.  
  - To prepare infusion: Mix 4 mg in 250ml (16 µg/ml). Titrate to desired effect. | Relatively contraindicated in hypovolemic patients.  
  - Should not be administered in the same IV line as alkaline solutions.  
  - Use with caution in patients with ischemic heart disease as myocardial O₂ requirements may ↑.  
  - Extravasation may result in tissue sloughing or necrosis. |
<table>
<thead>
<tr>
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<th>PRECAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procainamide</td>
<td>Suppresses ventricular ectopy. ↓ VF threshold.</td>
<td>Recommended when lidocaine is contraindicated or has failed to suppress ventricular ectopy.</td>
<td>IV infusion of 100 mg over 5 min (20 mg/min) until one of the following occurs:</td>
<td>↓ maintenance infusion in renal failure, CHF or liver dysfunction. Hypotension may occur if injected too rapidly – use caution in patients with acute MI. Avoid in patients with pre-existing QT prolongation and torsades de pointes.</td>
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<td></td>
<td>Shortens effective refractory period of the AV node.</td>
<td>Wide-complex tachycardias that cannot be distinguished from VT (not a first-line drug).</td>
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<tr>
<td></td>
<td>Prolongs effective refractory period and duration of the action potential in the His-Purkinje system.</td>
<td>Atrial fibrillation with a rapid ventricular response (not a first-line drug).</td>
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<td>Suppression of recurrent VT that cannot be controlled with lidocain.</td>
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<td>Refractory pulseless VT/VF.</td>
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<tr>
<td>Sodium Nitroprusside</td>
<td>Potent, rapid-acting peripheral vasodilator (arterial and venous) → ↓ preload and afterload.</td>
<td>Heart failure. Hypertension.</td>
<td>Add 50 mg to 250 ml (200 µg/ml). 0.1-5.0 µg/kg/min but higher doses (up to 10 µg/kg/min) may be needed.</td>
<td>IV and tubing should be wrapped in aluminum foil (deteriorates when exposed to light); use an infusion pump. Nitroglycerin preferred vasodilator in acute MI, especially when complicated by CHF. Primary complication is hypotension.</td>
</tr>
<tr>
<td>Trade Name: Nipride</td>
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<td>Other side effects:</td>
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<tr>
<td></td>
<td>↓ cardiac output.</td>
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<td>Headaches.</td>
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<td></td>
<td>↓ myocardial oxygen consumption.</td>
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<td>Nausea/vomiting.</td>
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<td>Abdominal cramps.</td>
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<td>Palpitations.</td>
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<td></td>
<td>Dizziness.</td>
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<td></td>
<td>Watch for thiocyanate toxicity:</td>
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<td></td>
<td></td>
<td></td>
<td>Confusion.</td>
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<td>Hypertreflexia.</td>
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<td>Convulsions.</td>
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<td>Tinnitus.</td>
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</table>
## Administration of TPN (continued)

<table>
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<th>PRECAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verapamil</td>
<td>Slows conduction and ↑ refractoriness in the AV node.</td>
<td>Narrow-complex PSVT (adenosine drug of choice).</td>
<td>2.5-5.0 mg slow IV bolus over 2 minutes.</td>
<td>Avoid or use with caution in left ventricular dysfunction.</td>
</tr>
<tr>
<td></td>
<td>May terminate reentrant dysrhythmias that require AV nodal conduc-</td>
<td>Atrial fibrillation or atrial flutter with a rapid ventricular response.</td>
<td>If no response, may repeat with 5-10 mg every 15-30 minutes to a maximum of 20 mg (if blood pressure normal or elevated).</td>
<td>Observe for hypotension.</td>
</tr>
<tr>
<td></td>
<td>tion for their continuation.</td>
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<td></td>
<td>Avoid in patients with AV block, sinus node dysfunction or severe cardiac failure.</td>
</tr>
<tr>
<td></td>
<td>May control ventricular response in patients with atrial fibrillation, atrial flutter or multifocal atrial tachycardia.</td>
<td>Wide-complex tachycardia KNOWN WITH CERTAINTY to be supraventricular in origin.</td>
<td>Administer over 3-4 minutes when treating the elderly or when the BP is within the lower range of normal.</td>
<td>Do not use in WPW with atrial fibrillation/flutter. Use cautiously in patients who receive long-term beta-blocker therapy.</td>
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<td>May ↓ myocardial contractility.</td>
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<td>May exacerbate CHF in patients with severe left ventricular dysfunc-</td>
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Monitoring Central Venous Pressure

Central venous pressure (CVP) measurements are widely used in both medical and surgical patients as a simple and easily available guide to fluid therapy after hemorrhage, accidental and surgical trauma, sepsis and emergency conditions associated with blood volume deficits.

Fluid Challenge Guideline Chart

Baseline Values:

<table>
<thead>
<tr>
<th>PAWP* MMHG</th>
<th>CHALLENGE VOLUME AMOUNT/10 MINUTES</th>
<th>CVP* MMHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 12 mmHg</td>
<td>200 ml or 20 cc/minute</td>
<td>&lt; 8 mmHg</td>
</tr>
<tr>
<td>12 - 16 - 18 mmHg</td>
<td>100 ml or 10 cc/minute</td>
<td>8 - 13 mmHg</td>
</tr>
<tr>
<td>&gt; 16 - 18 mmHg</td>
<td>50 ml or 5 cc/minute</td>
<td>&gt; 13 mmHg</td>
</tr>
</tbody>
</table>

- Re-profile at the end of 10 minutes or fluid challenge
- Discontinue challenge if PAWP increased > 7 mmHg or CVP increased > 4 mmHg
- Repeat challenge if PAWP increased < 3 mmHg or CVP increased < 2 mmHg
- Observe patient for 10 minutes and re-profile if PAWP increased > 3 mmHg but < 7 mmHg or CVP increased > 2 mmHg or < 4 mmHg
- Observe SVI and RVEDVI if RV volume values are available
- Discontinue challenge if: SVI fails to increase by at least 10% and RVEDVI increases by 25% or RVEDVI is > 140 ml/m2 and PAWP increases > 7 mmHg

OPTIONAL BASELINE RVEDVI VALUE GUIDELINES:
- If RVEDVI < 90 ml/m2 or mid range 90-140 ml/m2, administer fluid challenge
- If RVEDVI > 140 ml/m2, do not administer fluid

* References differ on PAWP and CVC ranges
Physiologic Rationale

Central venous catheters are used to measure the pressure under which the blood is returned to the right atrium and to give an assessment of the intravascular volume and right heart function. The CVP is a useful monitor if the factors affecting it are recognized and its limitations are understood. Serial measurements are more useful than individual values, and the response of the CVP to a volume infusion is a useful test of right ventricular function. The CVP does not give any direct indication of left heart filling but may be used as a crude estimate of left-sided pressures in patients with good left ventricular function.

Research Riches

Mangano demonstrated that CVP could be used to predict pulmonary artery wedge pressure in patients prior to, during, and after coronary artery surgery as long as the patients had ejection fractions greater than 0.50 with no angiographically demonstrable ventricular dyssynergy preoperatively.42

Essentially, CVP measurements reflect events in the cardiac cycle and, in so doing, depict cardiac function. During ventricular diastole, the AV valves are open, and each side of the heart is essentially unichambered. The pressure created by blood volume in the ventricles now extends back into the atria so that pressure measured in the right atrium indirectly mirrors the volume status of the right ventricle. Preload, or the volume status of the heart, has been measured as CVP or PAWP, for the right and left ventricles, respectively.
Physiologic Rationale (continued)

Mechanical Cardiac Cycle Phases

**SYSTOLE**

**Isovolumetric Phase**
Follows QRS of ECG
All valves are closed
Majority of oxygen consumed

**Rapid Ventricular Ejection**
Occurs during ST segment
80% to 85% of blood volume ejected

**Reduced Ventricular Ejection**
Occurs during “T” wave
Atria are in diastole
Produces “v” wave in atrial tracing

**DIASTOLE**

**Isovolumetric Relaxation**
Follows “T” wave
All valves closed
Ventricular pressure declines further
Ends in the ventricular “diastolic dip”

**Rapid Ventricular Filling**
AV valves open
Approximately two-thirds of blood volume goes into ventricle

**Slow Filling Phase: End-Diastole**
“Atrial Kick”
Follows “P” wave during sinus rhythms
Atrial systole occurs
Produces “a” wave on atrial tracings
Remaining volume goes into ventricle
Physiologic Rationale (continued)

Simplistically, by applying the principles expressed in Starling’s Law of the Heart, it can be deduced that if a patient’s CVP is low or normal, blood volume expanders may be given safely. This would serve to increase the presystolic (or end-diastolic) volume and therefore the ventricular muscle fibers, resulting in increased cardiac output. Conversely, as the CVP rises to higher levels, cardiac reserve decreases, and further blood volume administration becomes progressively more hazardous and less effective in increasing the work of the heart.

However, despite the apparent relationship between CVP and blood volume, it is incorrect to assess blood volume status from CVP. There are many factors that influence CVP values, not the least of which are cardiac performance, blood volume and vascular tone, intrinsic venous tone, increased intraabdominal or intrathoracic pressures and vasopressor therapy.

Sheldon and Leonard showed that, contrary to what one might expect clinically, arterial pressure and central venous pressure are relatively well maintained due to compensatory mechanisms until approximately 20-30% of the estimated blood volume has been extracted. Only then do these values begin to fall in a meaningful way.

Hemorrhage: 0.65 cc/kg/min

![Graph showing percent of baseline vs. estimated blood loss]
Physiologic Rationale (continued)

Upon resuscitation, CVP rises linearly but comes to baseline values prematurely. On the average, CVP returns to baseline after only 50% of the hemorrhage volume has been reinfused.

Clinical studies have shown that, in the presence of normal right heart function, severe deterioration of left ventricular function is not reflected in changes in CVP. Buchbinder, in 1976, demonstrated a wide range of pulmonary wedge pressures (left ventricular preload) obtained from patients in the presence of normal central venous pressure.

Figure 1. Data from 33 patients, showing the wide range of pulmonary capillary wedge pressure valves measured in the presence of normal central venous pressure (1-5 mm Hg).

HEMODYNAMIC MONITORING: INVASIVE TECHNIQUES

Neil Buchbinder, M.D. and William Ganz, M.D.

Prompt recognition and accurate assessment of serious circulatory changes in patients gravely ill or undergoing major surgical interventions is of critical importance. Although monitoring heart rate, arterial blood pressure, and central venous pressure has been a valuable guide, these values do not provide a sufficient basis for accurate diagnosis and proper management.
Physiologic Rationale (continued)

The value of central venous pressure is limited by the fact that it basically reflects the functional state of the right ventricle, which frequently does not parallel that of the left ventricle. Information about the function of the left heart is, however, often essential for proper evaluation. In recent years, techniques that allow easy monitoring and analysis of the function of both ventricles have become available. This paper describes these techniques and demonstrates how their use enables proper diagnosis and therapy of commonly encountered clinical situations.

Monitoring Techniques

Systemic Arterial Blood Pressure

In most situations, the sphygmomanometer accurately determines blood pressure. However, in some low-cardiac-output states, pulses may be poorly palpable, and Korotkoff sounds hard to hear while the intra-arterial pressure may be only moderately reduced. Monitoring of intra-arterial pressure is readily accomplished by percutaneous insertion of an 18- or 20-gauge sheath into a radial, brachial or femoral artery. With appropriate display systems, continuous pressure monitoring is obtained. Long-term patency is facilitated by intermittent flushing with 2-5 ml of heparinized 5% dextrose in water.

Right Heart and Pulmonary Vascular Pressures

While the right atrial (central venous) pressure can easily be measured at the bedside, catheterization of the pulmonary artery with semirigid catheters requires fluoroscopic guidance and substantial skill. Even in experienced hands, a risk of serious complications exists when severely ill patients are catheterized. These problems have been largely overcome by the introduction of balloon flotation catheters, which allow for rapid and relatively safe catheterization of the pulmonary artery without fluoroscopy.

Catheterization with Balloon Flotation Catheters

Catheterization can be performed in any hospital location where appropriate support devices are available for effective detection and therapy of arrhythmias and for recording hemodynamic data. Catheterization is performed during continuous electrocardiographic monitoring. The basilic, brachial, femoral, subclavian and internal jugular veins are used as insertion sites, the latter two being particularly preferred by anesthesiologists and surgeons.
Physiologic Rationale (continued)

After entry into the selected vein, the catheter is advanced until the tip is in or near the right atrium. This usually occurs after advancement for approximately 15 cm when the jugular or subclavian vein is used, after 40 cm with use of a vein in the right antecubital fossa, after 50 cm with use of a vein in the left antecubital fossa, and after about 30 cm when a femoral vein is used. Increase in respiratory fluctuation confirms that the catheter tip is in the thorax. At this time, the balloon is inflated to the recommended volume and the catheter advanced further. The catheter tip pressure is continuously recorded as the catheter proceeds from the right atrium into the right ventricle, pulmonary artery, and finally into a “wedge” position. At this point, the diameter of the balloon (11 or 13 mm) slightly exceeds that of the pulmonary artery. In the “wedge” position the tip senses the pressure transmitted with some delay and damping from the left atrium retrograde through the pulmonary veins and capillaries. With deflation of the balloon, pulmonary arterial pressure will reappear. Reinflation will cause the balloon to float into “wedge” position again.

As the catheter material (polyvinylchloride) softens with time, the transcardiac catheter loop tends to diminish, and this may result in migration of the catheter tip into smaller branches and into “wedge” position. Continuous or frequent (every 15 to 30 minutes) monitoring of pulmonary arterial pressure is, therefore, recommended. Inflation of the balloon to full capacity when the catheter tip is in a small branch of the pulmonary artery will result in a spuriously high pulmonary wedge pressure reading, caused by compression of the catheter lumen. Reinflation of the balloon should, therefore, be performed slowly, adding increments of 0.1 to 0.2 ml air until a change in pressure contour from pulmonary arterial to pulmonary wedge pressure is seen. If the pulmonary wedge pressure is obtained at a volume substantively less than the recommended inflation volume, the catheter should be gradually withdrawn (several cm) until the volume required for wedging is equal or nearly equal to the full inflation volume. When the balloon is deflated, the ideal catheter position is with the tip in one of the primary branches of the pulmonary artery.

One of the most important applications of the balloon flotation catheter is in the recording of the pulmonary capillary wedge pressure obtained when the inflated balloon impacts into a slightly smaller branch of the pulmonary artery. The pulmonary
Physiologic Rationale (continued)

capillary wedge pressure is of great significance in clinical practice in that it provides information about two important determinants of cardiopulmonary function. First, the level of this pressure is a basic factor in pulmonary congestion and in the shift of fluid from the pulmonary capillaries into the interstitial tissue and alveoli. Second, the pulmonary capillary wedge pressure closely reflects left atrial pressure and can, therefore, serve as an index of left ventricular filling pressure.

The mean pulmonary capillary wedge and left atrial pressures closely approximate left ventricular end-diastolic pressure in patients who have normal left ventricular and mitral valve function. In left ventricular failure, the elevated left ventricular end-diastolic pressure may significantly exceed the mean left atrial and accordingly, pulmonary capillary wedge pressure. Nevertheless, in clinical practice the mean pulmonary capillary wedge pressure has proved to be a reliable and useful index of left ventricular filling, and as such provides highly relevant information on the function of the left ventricle.

Since the pulmonary vasculature is a low-resistance circuit, the pulmonary arterial end-diastolic pressure is normally only slightly higher (1 to 3 mm Hg) than the mean pulmonary capillary wedge pressure and can, therefore, be used as an index of left ventricular filling, when the pulmonary capillary wedge pressure is not obtainable. However, in states associated with high pulmonary vascular resistance, the pulmonary arterial end-diastolic pressure may markedly exceed the mean pulmonary capillary wedge pressure.

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Physiologic Rationale (continued)

Additionally, central venous pressure is a **pressure**-based measurement used to assess volume. The relationship of pressure to volume is not a linear one. Actually this relationship is expressed by a family of **compliance curves** that change in response to various clinical situations and/or therapeutic interventions. *For further information on this technology, please refer to literature on Edwards’ Right Ventricular Ejection Fraction (REF) catheter.*

![Compliance Curves Diagram](chart.png)


**CAVEATS**

1. CVP **only** indicates the relationship between circulating blood volume and the capacity of the heart to handle it at any particular time.

2. A low CVP **may** indicate hypovolemia while a high CVP **may** indicate hypervolemia; however, a high CVP may also indicate a need for positive inotropes to pump the existing fluid volume more effectively.

3. The **trend** of the venous pressure and the response to therapy is often more significant than the actual level of an isolated venous pressure determination.
Physiologic Rationale (continued)

CVP Interpretation (CVP Range 2-6 mm Hg)

<table>
<thead>
<tr>
<th>INCREASED CVP</th>
<th>DECREASED CVP</th>
</tr>
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<tbody>
<tr>
<td>Increased venous return from conditions that cause hypervolemia</td>
<td>Decreased venous return and hypovolemia</td>
</tr>
<tr>
<td>Depressed cardiac function</td>
<td>Loss of vascular tone caused by vasodilation (sepsis) which contributes to venous pooling and reduced blood return to the heart</td>
</tr>
</tbody>
</table>

Cardiac tamponade
Pulmonary hypertension
PEEP
Vasoconstriction

Clinical Assessment

Various studies have documented that it is unreliable to assess central venous pressure by clinical assessment alone. In 1983, Connors et al. prospectively evaluated 62 right heart catheterizations performed on critically ill patients with no evidence of a recent acute myocardial infarction to determine whether the hemodynamic measurements obtained could have been predicted by physical examination and review of the chest x-ray. Additionally, they looked at whether the procedure led to changes in therapy. They found that estimates of the patient’s hemodynamic status based on physical examination were frequently in error and that catheterization often prompted a change in therapy.

Specifically, in each medical intensive care unit, a team of physicians consisting of an attending physician, a critical-care fellow, a third-year resident, an intern, and frequently a fourth-year medical student determined the need for catheterization and the current therapy and formulated theoretical plans for therapy to be followed if catheterization data were not available. In 48.4% of all the cases studied, information obtained through catheterization prompted a change in therapy.
Clinical Assessment (continued)

Research Riches
Eisenberg et al examined 97 ICU patients to determine the accuracy of clinical diagnosis compared to measurement by pulmonary artery catheterization. Clinical assessment correctly predicted right atrial pressure approximately 50% of the time. Overall, planned therapy was altered by the information obtained from catheterization in 58% of all the cases. In 30%, a new (unanticipated) therapy was added after catheterization.⁴⁶

Research Riches
In 1990, Cook examined 50 consecutive intensive care patients with right internal jugular catheters. She also found considerable disagreement and inaccuracy in the clinical assessment of central venous pressure in critically ill patients.⁴⁷

Research Riches
Cook noted that the predictions of attending physicians and critical care fellows were no more accurate than those of house staff and medical students. Cook also noted that physicians are better at identifying low CVP and more accurate when ventilated patients are excluded from the study.
Manometric versus Electronic Measurement

The use of water manometers for the measurement of central venous pressure has been surpassed by use of the disposable pressure transducer. Two studies in the mid-1980s reported that manometric values of central venous pressure differed from those obtained electronically. Despite correct position of the catheter tips and adequate respiratory oscillations, manometric measurements differed considerably from right atrial mean pressure determinations. Both investigators recommended that water manometry for the measurement of central venous pressure not be used in the critical care environment.

CVP Monitoring Set-Up

Pressure Monitoring System

The typical invasive pressure monitoring system consists of:

- **Noncompliant tubing** – to accurately transmit pressure waveforms to the transducer
- **Disposable transducer** – to accurately amplify the signal
- **Monitor cable** – to accurately transmit the amplified signal to the monitor
CVP Monitoring Set-Up (continued)

Additional components include:

- **Pressurized solution** – pressurized to at least 300 mm Hg
- **Integral flush device with a restrictor** – to limit flow rate to approximately 3 to 5mL/hr for adults
- **Heparinized solution** – 0.9% NS with Heparin 0.5-2 U/mL

**CATHETER TUBING COMPONENT**

This system, incorporating the catheter, tubing, and associated stopcocks, must be fluid-filled for the waveform to be reproduced accurately. Fluid is essentially non-compressible and allows the waveform signal to be transmitted across relatively long distances.

One factor likely to alter the waveform signal is the length of the tubing. The longer the tubing, the more likely the waveform will be distorted. As a general rule, the tubing should be kept as short as possible to obtain accurate waveforms.

The top trace represents a valid arterial waveform. The bottom trace represents the same waveform distorted by increased length of tubing.

**Air bubbles** are compressible and will, therefore, also distort the waveform signal. Blood in the tubing will also absorb more of the waveform signal than normal saline.

The top trace represents a valid arterial waveform. The bottom trace represents the same trace when distorted by an air bubble in the line.
CVP Monitoring Set-Up (continued)

*Nursing Note*
Although the difference in pressures recorded may not be clinically significant in these examples of arterial lines, mean CVP values range between 2-6 mm Hg; even a small difference (related to air bubbles or length of tubing) may appear *clinically* significant.

**Overdamping** results in a waveform losing its definition. Systolic pressure decreases and diastolic pressure increases. Several factors could cause damping:
- Fibrin at catheter tip
- Catheter tip against wall of vessel
- Air bubbles or blood in the system

![Damped Waveform](image)

*Nursing Note*
If a clot is suspected, *aspirate first*; then flush gently.

**FREQUENCY RESPONSE**
Frequency response and damping coefficient measure the overall system’s ability to accurately reproduce a signal; in this case, a pressure tracing. The *square wave test* is an easy one to perform and interpret at the bedside. Most commercial fast flush systems, once activated, produce a rapid rise in pressure that goes off the scale of the monitoring system. This squares off the tracing. Upon release of the flush device, the pressure waveform then rapidly returns to baseline.
CVP Monitoring Set-Up (continued)

SQUARE WAVE TESTING
1. Activate snap or pull tab on flush device.
2. Observe square wave generated on bedside monitor.
3. Count oscillations after square wave.
4. Observe distance between the oscillations.

Optimally Damped:
1 - 2 oscillations before returning to tracing. Values obtained are accurate.

Underdamped:
> 2 oscillations.
Overestimated systolic pressure, diastolic pressures may be underestimated.

Overdamped:
< 1 1/2 oscillations.
Underestimation of systolic pressures, diastolic may not be affected.

CALIBRATION
It is no longer important to calibrate the transducer, as the disposable transducer systems currently in use today have an accuracy rate of 1-2%. If inaccuracy is suspected, the transducer is usually replaced after the monitoring cable has been replaced and found not at fault.

ZERO REFERENCE
The accuracy of the CVP is determined, in part, by transducer placement relative to an external reference point on the patient’s body representing the location of the right atrium. Since its identification in 1945, the phlebostatic axis has been repeatedly confirmed as a valid external reference point for CVP, LAP and PAP measurements. It has been anatomically shown to be a true external point for identifying the right atrium when the patient is supine.
The method to zero reference the pressure monitoring system requires placement of the air-fluid interface at the level of the phlebostatic axis. The stopcock located at the designated air-fluid interface is then opened to air, allowing for the influence of atmospheric pressure to be eliminated. Usually, this stopcock is located at the transducer but may be located anywhere within the line itself. Once the leveling has been accomplished, the patient and transducer must remain in the same position. If the head of the patient’s bed is elevated, then re-leveling needs to be repeated in the new position.

(Reproduced with permission from Woods SL, et. al.: Cardiac Nursing. J.B. Lippincott Co., Third Edition.)
**CVP Monitoring Set-Up (continued)**

**Practical Point**
The only exception to re-zeroing with patient movement is to mount the transducer on the patient. When **patient-mounted**, the transducer will not lose its relationship to the phlebostatic axis as long as the movement is in the same plane (i.e., the patient cannot be turned laterally).

**Patient Position**
The literature suggest that accurate CVP measurements can be obtained with the adult and pediatric patient in the supine position in **various degrees of backrest up to 30 degrees**. Additionally, the effect of tilting on CVP measurement has been investigated and accuracy maintained with the use of the phlebostatic axis as the zero reference point.

**Physiology Fact**
Actually, it is sometimes suggested that, in the assessment of circulatory volume depletion, CVP should be measured with the patient at 45 degrees as measurement of CVP in the supine position may not detect or may severely underestimate circulatory volume depletion.49

The evidence supporting use of the phlebostatic axis to yield accurate CVP values in the **lateral position** is less clear. In the studies on pressure measurement in patients in the lateral position, the phlebostatic axis yielded more reproducible values between the supine and lateral positions than other postulated reference levels.

Potger and Elliott50 studied the lateral position when the transducer was leveled at the supine phlebostatic axis and was not re-leveled when the patient was turned 30 degrees to the right or left lateral position with the head of the bed elevated 20 degrees. Although there was no statistical significance, there were **clinically significant** changes. They suggested an alternative approach involving the identification of the transducer placement in the patient in the lateral position that yielded the same CVP reading as that obtained in the supine position.
If there is any doubt about the CVP value obtained in the patient in the lateral position, the patient should be returned to the supine position for re-measurement.

An interesting point to consider is the minimum stabilization period after patient repositioning. Unfortunately, this has not been determined. However, it is prudent not to determine pressure measurements immediately after repositioning. It should also be remembered that, in elderly and critically ill patients, the change in position may have a greater contribution to variations in pressure than the position itself.

Port Site
Measurement of CVP is usually performed through one of the ports of a triple-lumen central venous catheter. In a study by Scott et al., measurements of CVP in 48 adult intensive care patients were obtained via each of the three ports of a triple-lumen CVC. Catheters were placed in either the right or left subclavian vein or the right or left internal jugular vein. The data showed significant differences across port sites. There were significant differences between the proximal and distal ports and between the medial and distal ports. In some patients, the difference between CVP obtained from the distal port and pressure obtained from the proximal or the medial port could have been clinically significant. It would make sense to assure that CVP readings be standardized to a specific port to enhance validity of data and that the port utilized is documented in the clinical notes.

Respiratory Influences
During spontaneous breathing, inspiration causes a decrease in intrathoracic pressure that is transmitted in part to the right atrium and produces a decline in CVP. The opposite is true when the patient is receiving mechanical ventilation. Most clinicians measure end-expiratory values for cardiac filling pressures, because both pleural and pericardial pressures approach atmospheric pressure under these conditions, whether the patient is breathing spontaneously or receiving positive pressure mechanical ventilation. These pressure values can be determined by visual inspection of the CVP waveform on a calibrated monitor screen or digital printout.
Physiology Fact
Ventilatory support with positive pressure usually elevates the central venous pressure only slightly (0-2 mm Hg). However, if more effective ventilation and oxygenation improve pump function, the CVP may decrease as a result of the positive pressure ventilation.
CVP Monitoring Set-Up (continued)

Infection Control for Pressure Lines

It is interesting to note that **gram-negative** microorganisms account for the majority of catheter-related infections associated with the use of pressure monitoring systems. Apparently, such systems are considerably more vulnerable to becoming contaminated during use. This may stem from the presence of a stagnant column of fluid subjected to frequent manipulations. Studies suggest that if the infusion for hemodynamic monitoring is set up so that it flows continuously, it may not be necessary to routinely change out at 24-48 hour intervals. With the use of disposable transducers, **there appears to be no need to replace the transducer and other components of the delivery system more frequently than every four days.**

**CDC Guideline (1996)**

- Use disposable, rather than reusable, transducer assemblies whenever possible.
- Replace disposable or reusable transducers at 96 hour intervals. Replace other components of the system, including the tubing, continuous flush device, and flush solution, at the time the transducer is replaced.
- Keep sterile all components of the pressure monitoring circuit (including calibration devices and flush solution).
- Minimize the number of manipulations and entries into the pressure monitoring system. Use a closed-flush (i.e., continuous flush), rather than an open system (i.e., one that requires a syringe and stopcock), to maintain patency of the pressure monitoring catheters. If stopcocks are used, treat them as a sterile field, and cover them with a cap or syringe when not in use.
- When the pressure monitoring system is accessed through a rubber diaphragm rather than a stopcock, wipe the diaphragm with appropriate antiseptic before accessing the system.
- Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit.
- Do not routinely use pressure monitoring devices to obtain blood samples that do not require arterial blood.
### Troubleshooting Pressure Monitoring Systems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Causes/Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Waveform</td>
<td>Check power supply.</td>
</tr>
<tr>
<td></td>
<td>Check the pressure range setting on the monitoring equipment.</td>
</tr>
<tr>
<td></td>
<td>Check balancing and calibration of the equipment.</td>
</tr>
<tr>
<td></td>
<td>Check for loose connection in the IV pressure line.</td>
</tr>
<tr>
<td></td>
<td>Check to be certain that Stopcocks are not turned off to the patient.</td>
</tr>
<tr>
<td></td>
<td>It is possible that the catheter is occluded or has moved out of the vessel. If this is suspected, try to aspirate blood from the line. <strong>NOTE:</strong> Fast-flushing the line may dislodge a clot. Never apply pressure to the irrigating syringe greater than that used for a standard IM injection.</td>
</tr>
<tr>
<td>Artifact</td>
<td>Check for electrical interference.</td>
</tr>
<tr>
<td></td>
<td>Check for patient movement.</td>
</tr>
<tr>
<td></td>
<td>Catheter whip may be the problem.</td>
</tr>
<tr>
<td>Waveform Drifting</td>
<td>Temperature change of IV solution (new flush bag hung) or environment.</td>
</tr>
<tr>
<td></td>
<td>Be certain the electrical monitoring cable is not kinked or compressed.</td>
</tr>
<tr>
<td>Unable to Flush Line</td>
<td>Check stopcocks and tubing for kinks.</td>
</tr>
<tr>
<td>Reading Too High</td>
<td>Check to see if the transducer is located at the appropriate level.</td>
</tr>
<tr>
<td></td>
<td>Check stopcocks to make certain they are open to the patient.</td>
</tr>
<tr>
<td></td>
<td>Suspect failure of the automatic flush device (flow too fast).</td>
</tr>
<tr>
<td>Reading Too Low</td>
<td>Check to see if the transducer is located at the appropriate level.</td>
</tr>
<tr>
<td></td>
<td>Check for loose connections</td>
</tr>
<tr>
<td>Dampened Waveform</td>
<td>Check for air bubbles in the system.</td>
</tr>
<tr>
<td></td>
<td>Check for kinks in the tubing.</td>
</tr>
<tr>
<td></td>
<td>Suspect possible occlusion at the catheter tip (ie, thrombus) or the catheter tip may be resting against the vessel wall. <strong>NOTE:</strong> A term sometimes used is “high pressure damping.” This refers to a baseline that elevates and remains elevated – usually at the upper limit of the pressure monitoring range. This is invariably caused either by an electrical failure of the monitor/amplifier or by total occlusion at some point in the fluid-filled line. Check stopcocks, tubing and catheter patency.</td>
</tr>
</tbody>
</table>

(Reproduced with permission from Darovic GO: Hemodynamic Monitoring, Invasive and Noninvasive Clinical Application. W.B. Saunders)
Normal CVP Waveform

Waveforms seen on the monitor merely reflect the intracardiac events. The normal CVP waveform consists of three peaks (a, c and v waves) and two descents (x and y). The a wave represents atrial contraction and follows the P wave on the EKG trace. This is the atrial kick that loads the right ventricle just prior to contraction. As atrial pressure decreases, a c wave, resulting from closure of the tricuspid valve, may be seen. The x descent represents the continually decreasing atrial pressure. The v wave represents the atrial events during ventricular contraction – passive atrial filling – and follows the T wave on the EKG. When the atrial pressure is sufficient, the tricuspid valve opens, and the y descent occurs. Then the cycle repeats.

Accurate recognition of these waves requires that they be aligned with an EKG trace. As mechanical events follow electrical events, the waveforms can be identified by lining them up with the EKG events. Although the arterial pressure trace can be used for timing, this may be confusing due to the time delay involved in transmitting the aortic pressure to the radial artery.

Waveform 6–7. Reading CVP waveforms with spontaneous inspiratory artifact.
Abnormal Waveform Analysis

Arrhythmias

Since electrical events determine the mechanical, there will be no a waves in atrial fibrillation. Occasionally, fibrillation waves may be seen in the CVP trace when the atrial fibrillation is coarse and the rate is slow. Atrioventricular dissociation or junctional rhythm results in cannon a waves. This is due to atrial contraction occurring during ventricular systole when the tricuspid valve is closed. Ventricular pacing can be identified in similar fashion by searching for cannon waves in the venous pressure trace.
Abnormal Waveform Analysis (continued)

These three conditions may cause arterial hypotension due to loss of atrial kick, and the venous trace may help with diagnosis.

This patient, with atrial fibrillation, has no identifiable \textit{a} waves. Small flutter or fibrillation waves may be evident. Only \textit{v} waves can be seen following each QRS complex on the EKG.

Key: 1 = \textit{v} wave
2 = \textit{y} descent

This patient has AV dissociation with a demand pacemaker. The underlying atrial activity (\textit{p} waves) is indicated by arrows. When \textit{p} waves occur causing the atria to contract against a closed tricuspid valve, \textit{cannon a} waves occur.

Key: 1 = \textit{a} wave
2 = \textit{v} wave
3 = \textit{cannon a} wave

In this CVP tracing, there are normal \textit{a} and \textit{v} waves. Following a PVC, a large \textit{v} wave is noted. As the AV valve was open during the premature beat, blood goes back into the right atrium during early contraction.

Key: 1 = \textit{a} wave
2 = \textit{v} wave
3 = \text{large v} wave
Abnormal Waveform Analysis (continued)

Tricuspid Valve Disease

Tricuspid regurgitation produces giant \( v \) waves as abnormal systolic filling of the right atrium through the incompetent valve occurs during ventricular systole. Right ventricular end diastolic pressure is overestimated by the numeric readout on the bedside monitor that reports a single mean value for CVP. Reading the waveform at the top of the \( a \) wave might prove a better indicator of right ventricular filling.

In this CVP trace, both \( a \) and \( v \) waves are elevated. However, the \( v \) wave is dominant and reflects tricuspid insufficiency. The elevated \( a \) wave demonstrates a degree of right ventricular failure as well.

Key: 1 = \( a \) wave  
2 = \( c \) wave  
3 = \( v \) wave

Tricuspid stenosis usually presents with an increased \( a \) wave that represents the increased force of atrial contraction to push blood across the stenotic valve. In this instance, CVP readings will be falsely elevated. Right ventricular filling may actually be decreased due to the valvular obstruction.

Right Ventricular Infarction

This condition causes a disproportionate elevation of CVP compared to PAWP. Often the CVP will exceed wedge pressure and display prominent \( a \) and \( v \) waves, the former suggesting atrial contraction into a stiff or incompletely relaxed right ventricle, and the latter suggesting tricuspid valve regurgitation, which is often associated with this condition.
Abnormal Waveform Analysis (continued)

In this patient with a right ventricular infarction, right ventricular compliance is decreased due to myocardial injury. The right atrium must generate a much higher pressure during systole to pump blood into the compromised right ventricle, resulting in a dominant \( a \) wave. The \( v \) wave is somewhat elevated due to right ventricular failure.

Key 1 = \( a \) wave  2 = \( v \) wave  (Note that the PAWP trace is normal.)

Pericardial Constriction/Cardiac Tamponade

In these conditions, the pericardium or an increase in pericardial fluid limits venous return to the heart. This, in turn, reduces stroke volume and cardiac output. Central venous pressure is elevated, and there is end-diastolic pressure equalization in all cardiac chambers. Characteristic of the pressure trace is an \( M \) or \( W \) configuration secondary to prominent \( a \) and \( v \) waves and steep \( x \) or \( y \) descents.

In this patient with cardiac tamponade, both \( a \) and \( v \) waves are elevated reflecting the elevated diastolic filling pressures in all cardiac chambers. This diastolic plateau results from diastolic compression of the heart by the blood or fluid in the pericardial sac. There is a prominent \( x \) descent and a very short \( y \) descent.

Key 1 = \( a \) wave  2 = \( c \) wave  3 = \( v \) wave

Please see Edwards slide module Waveform Analysis for further information.
Abnormal Waveform Chart

RIGHT ATRIAL WAVEFORMS

Decreased mean pressure
- Hypovolemia
- Transducer zero level too high

Elevated mean pressure
- Fluid overload states
- Right ventricular failure
- Left ventricular failure causing right ventricular failure
- Tricuspid stenosis or regurgitation
- Pulmonic stenosis or regurgitation
- Pulmonary hypertension

Elevated “a” wave: atrial systole, increased resistance to ventricular filling
- Tricuspid stenosis
- Decreased right ventricular compliance
- Right ventricular failure
- Pulmonic stenosis
- Pulmonary hypertension

Absent “a” wave
- Atrial fibrillation
- Atrial flutter
- Junctional rhythms: cannon “a” waves

Elevated “v” wave: atrial filling, regurgitant flow
- Tricuspid regurgitation
- Functional regurgitation from right ventricular failure

Elevated “a” and “v” waves
- Cardiac tamponade
- Constrictive pericardial disease
- Hypovolemia
- Right ventricular failure
Abnormal Waveform Analysis (continued)

Abnormal Waveform Chart (continued)

RIGHT VENTRICULAR WAVEFORMS

Elevated systolic pressure
  - Pulmonary hypertension
  - Pulmonic valve stenosis
  - Factors that increase pulmonary vascular resistance

Decreased systolic pressure
  - Hypovolemia
  - Cardiogenic shock
  - Cardiac tamponade

Increased diastolic pressure
  - Hypervolemia
  - Congestive heart failure
  - Cardiac tamponade
  - Pericardial constriction

Decreased diastolic pressure
  - Hypovolemia

PULMONARY ARTERY WAVEFORMS

Elevated systolic pressure
  - Pulmonary disease
  - Increased pulmonary vascular resistance
  - Mitral stenosis or regurgitation
  - Left heart failure
  - Increased blood flow; left to right shunt

Reduced systolic pressure
  - Hypovolemia
  - Pulmonic stenosis
  - Tricuspid stenosis
Abnormal Waveform Analysis

CASE STUDY

Patient Profile
A 72-year-old male with a history of arteriosclerotic heart disease and chronic obstructive lung disease was admitted to the intensive care unit following coronary artery bypass grafting of the left anterior descending and circumflex arteries. The following data are obtained four hours postoperatively:

<table>
<thead>
<tr>
<th>B/P (S/D/M)</th>
<th>90/60/73 mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>100 bpm</td>
</tr>
<tr>
<td>RAP/CVP</td>
<td>17 mm Hg</td>
</tr>
<tr>
<td>Urine Output</td>
<td>10 mL/hr</td>
</tr>
</tbody>
</table>

The patient is receiving Dopamine at 5 mcg/kg/min.

Diagnosis
The decreased blood pressure, elevated heart rate, and decreased urinary output might point to pump failure. The high CVP seems to support this diagnosis. Remember the patient is already receiving inotropic support.

Does this patient have right heart failure secondary to his chronic lung disease and/or being on cardiopulmonary bypass?

Analysis
One might think that the diagnosis of right heart failure is justified based on these findings, and an increase in inotropic support might be indicated. However, what additional hemodynamic information can be gleaned from this patient? The RAP/CVP waveform can be recorded and analyzed for any clues. The waveform is characterized by:

- Elevated mean pressure
- Prominent \(a\) and \(v\) waves
- Exaggerated \(x\) descent

This waveform is suggestive of cardiac tamponade – or a dry heart unable to fill secondary to compression.

If a pulmonary artery catheter were inserted, the following hemodynamic data would be obtained:

<table>
<thead>
<tr>
<th>CO</th>
<th>3.0 L/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>1.5 L/min</td>
</tr>
<tr>
<td>PAWP</td>
<td>18 mm Hg</td>
</tr>
<tr>
<td>PAP</td>
<td>50/20 mm Hg</td>
</tr>
</tbody>
</table>
Abnormal Waveform Analysis (continued)

The elevated wedge pressure and decreased cardiac output are indicative of both heart failure (biventricular) and cardiac tamponade. However, whenever the PAWP and RAP equalize (diastolic plateau), cardiac tamponade should at least be suspected.

Results

The patient did indeed have cardiac tamponade and was returned to the operating room for evacuation of a clot.

Summary

The original treatment of increasing inotropic support would not have been appropriate. The patient actually needed fluid administration (contrary to what might be anticipated by the increased CVP). Analysis of the right atrial waveform would have provided increased impetus to obtain an echocardiogram for definitive diagnosis.

This is not an abstract scenario. Collier’s work on previously unrecognized cardiac tamponade secondary to central line placement should be reviewed. He stated that significant diagnostic clues might be:

- Worsening of hypotension after the administration of nitrates. The nitrates reduce the venous return and worsen the physiology of cardiac tamponade; i.e., an already dry heart is now made drier.
- Worsening of hypotension shortly after intubation. The negative intrathoracic pressure during normal respiration pulls blood back into the heart as a compensatory mechanism for the tamponade. Intubation converts this negative pressure to positive pressure. This dramatically reduces the venous return to the heart, and the cardiac output falls, usually leading to a precipitous drop in blood pressure.

Waveform analysis to differentiate right ventricular infarction, constrictive pericarditis and cardiac tamponade can be very specific.
Additionally, the use of a right heart ejection fraction catheter (RHEF) would have provided the following data:

<table>
<thead>
<tr>
<th></th>
<th>normal range 30-40%</th>
<th>contractility OK</th>
<th>hypovolemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVEF</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVedv</td>
<td>60 mL</td>
<td>100-160 mL</td>
<td></td>
</tr>
</tbody>
</table>
Advanced Venous Access (AVA) Devices

AVA High Flow (HF)

The AVA HF device integrates the capabilities of an introducer and multi-lumen central venous access into one device. Unlike standard introducers, the AVA HF device incorporates three independent lumens that function similar to multi-lumen lines. The AVA HF device may eliminate the need to place both a central venous catheter and a pulmonary artery catheter in the high-risk surgical patient. Similarly, a pulmonary artery catheter can be quickly inserted through the introducer lumen when more invasive cardiac monitoring is required.

The AVA HF (9F) incorporates a tri-lumen sheath design with inner flexible walls so that the individual lumen size can vary. The cross section increases from a 15 gauge lumen under standard gravity (101.6cm head height), to 12 gauge when infusing fluids under pressure at 300 mm Hg (without a catheter through the distal lumen).

<table>
<thead>
<tr>
<th>AVA HF DEVICE – FLOW RATES (WITHOUT PAC)</th>
<th>GRAVITY</th>
<th>UNDER PRESSURE (300 MM HG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal 1 and 2 combined</td>
<td>161 mL/min</td>
<td>1,202 mL/min</td>
</tr>
<tr>
<td>Distal lumen only</td>
<td>555 mL/min</td>
<td>1,293 mL/min</td>
</tr>
<tr>
<td>All 3 lumens simultaneously</td>
<td></td>
<td>1,492 mL/min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AVA HF DEVICE – FLOW RATES (WITH 8F PAC)</th>
<th>GRAVITY</th>
<th>UNDER PRESSURE (300 MM HG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal 1 and 2 combined</td>
<td>161 mL/min</td>
<td>560 mL/min</td>
</tr>
<tr>
<td>Distal lumen only</td>
<td>60 mL/min</td>
<td>169 mL/min</td>
</tr>
</tbody>
</table>

Flow rates shown using normal saline, room temperature.
Practical Point
AVA HF may replace the need for a double-stick, discussed earlier. Only one site to manage!

AVA 3Xi
The AVA 3Xi device is a true multifunctional access device – a triple lumen device and introducer combined. Designed with the needs of the routine and fast-track cardiac surgery patient in mind, the AVA 3Xi incorporates three independent lumens with flexible walls and staggered infusion exit ports. The addition of a detachable introducer valve allows the introduction of a pulmonary artery catheter through the existing triple lumen device at any time. This is made possible through the anti-bleedback septum (ABS) that is permanently attached to the distal lumen. This septum ensures that the distal lumen remains sealed when not in use and allows for access with any male luer connection.
### Advanced Venous Access (AVA) Devices (continued)

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>BENEFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detachable introducer valve</td>
<td>Provides flexibility for evolving central venous access requirements</td>
</tr>
<tr>
<td>Anti-bleedback septum</td>
<td>Maintains hemostasis when not in use</td>
</tr>
<tr>
<td></td>
<td>Allows patient transfer to stepdown or telemetry unit when introducer is removed</td>
</tr>
<tr>
<td></td>
<td>Compatible with any male luer connection (IV tubing, pressure tubing or syringe)</td>
</tr>
<tr>
<td>Locking contamination shield</td>
<td>Secures PA catheter at both proximal and distal locations</td>
</tr>
</tbody>
</table>

### Helpful Hints

Flush all 3 lumens with heparinized saline prior to insertion. Be sure that the introducer is attached to the anti-bleedback septum on the distal lumen before inserting dilator. (Do not insert dilator directly into anti-bleedback septum.)

To ensure proper attachment to introducer valve or any male luer to the ABS, follow these steps.

1. Align desired male luer with ABS
2. Push male luer into ABS (straight - not at an angle).
3. Rotate male luer device clockwise to tighten.
4. Ensure that connection is secure.

Insert the pulmonary artery catheter at least 25 cm before inflating the balloon to be sure that the PAC has exited the tip of the introducer sheath.

Do not pierce anti-bleedback septum with a needle. Use a luer syringe to attach directly to the anti-bleedback septum. Draw blood samples from the distal lumen.
Advanced Venous Access Devices (continued)

**COMPARISON OF ADVANCED VENOUS ACCESS DEVICES**

<table>
<thead>
<tr>
<th></th>
<th><strong>AVA HF</strong></th>
<th><strong>AVA 3Xi</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Type</strong></td>
<td>High-risk medical/surgical patients</td>
<td>Fast-track and routine cardiac surgical patients involving multiple access lines</td>
</tr>
<tr>
<td></td>
<td>High infusion/volume need</td>
<td></td>
</tr>
<tr>
<td><strong>Introducer Lumen Size</strong></td>
<td>9F</td>
<td>8.5F</td>
</tr>
<tr>
<td><strong>PAC French Size</strong></td>
<td>Up to 8F PAC</td>
<td>Up to 7.5F PAC</td>
</tr>
<tr>
<td><strong>Lumen Volumes</strong></td>
<td>Distal 2.7 mL</td>
<td>Distal 1.5 mL</td>
</tr>
<tr>
<td></td>
<td>Proximal 1 1.6 mL</td>
<td>Medial 0.5 mL</td>
</tr>
<tr>
<td></td>
<td>Proximal 2 1.6 mL</td>
<td>Proximal 0.5 mL</td>
</tr>
<tr>
<td><strong>AVA Port Color Designation</strong></td>
<td>Distal – Brown</td>
<td>Distal – ABS</td>
</tr>
<tr>
<td></td>
<td>Proximal 1 – Blue</td>
<td>Medial – Blue</td>
</tr>
<tr>
<td></td>
<td>Proximal 2 – Grey</td>
<td>Proximal – White</td>
</tr>
<tr>
<td><strong>AVA Port Exit Locations (from Distal tip)</strong></td>
<td>Distal – tip</td>
<td>Distal – tip</td>
</tr>
<tr>
<td></td>
<td>Proximal 1 – 1.5 cm</td>
<td>Medial – 1.0 cm</td>
</tr>
<tr>
<td></td>
<td>Proximal 2 – 1.5 cm</td>
<td>Proximal – 2 cm</td>
</tr>
</tbody>
</table>

Advanced Venous Access devices (both AVA HF and AVA 3Xi) are available with or without AMC THROMBOSHIELD (an Antimicrobial* Heparin Coating) and Interlink components, in basic set or expanded kit trays.

*Decreases viable microbe count on surface of catheter during handling and placement.

Antimicrobial activity associated with AMC THROMBOSHIELD has been demonstrated using in vitro agar diffusion assays against the following organisms: Staphylococcus epidermidis, Staphylococcus aureus, Enterococcus faecalis, Candida albicans, Escherichia coli, Serratia marcescens and Acinetobacter calcoaceticus.

Central Venous Catheters (CVC)

**Vantex Central Venous Catheters with Oligon Material**

Vantex CVCs provide antimicrobial protection through the use of a new material called Oligon. Silver, platinum and carbon are combined with a base material of polyurethane. When the catheter is inserted, body fluids interact with the silver and platinum particles in the material, causing a release of silver ions the catheter. Antimicrobial activity on the Oligon surface and inner lumens of the catheter during handling and placement has been demonstrated through in vitro testing against organisms commonly associated with nosocomial infections.
The activity of the antimicrobial agents is localized at the catheter surfaces and is not intended for treatment of systemic infections. 

In vitro testing demonstrated that the Oligon material provided broad spectrum effectiveness (≥ 3 log reduction from initial concentration within 48 hours) against the organisms tested: Staphylococcus aureus, Staphylococcus epidermidis, Klebsiella pneumoniae, Enterococcus faecalis, Candida albicans, Escherichia coli, Serratia marcescens, Acinetobacter calcoaceticus, Corynebacterium diptheriae, Enterobacter aerogenes, GMRSA, and Pseudomonas aeruginosa. The impact of Oligon material on infection rates has not been demonstrated.

DOUBLE LUMEN
Available as catheter only, basic sets and expanded kit trays, with and without heparin coating, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7F</td>
<td>16/16</td>
<td>16 cm</td>
</tr>
<tr>
<td>7F</td>
<td>16/16</td>
<td>20 cm</td>
</tr>
<tr>
<td>8.5F</td>
<td>14/15</td>
<td>16 cm</td>
</tr>
<tr>
<td>8.5F</td>
<td>14/15</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

TRIPLE LUMEN
Available as catheter only, basic sets and expanded kit trays, with and without heparin coating, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7F</td>
<td>18/18/16</td>
<td>16 cm</td>
</tr>
<tr>
<td>7F</td>
<td>18/18/16</td>
<td>20 cm</td>
</tr>
</tbody>
</table>
Central Venous Catheters (CVC)  (continued)

**QUAD LUMEN**
Available as catheter only, basic sets and expanded kit trays, with and without heparin coating, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5F</td>
<td>15/18/18/18</td>
<td>16 cm</td>
</tr>
<tr>
<td>8.5F</td>
<td>15/18/18/18</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

**Commercial Comment**
Since Edwards’ Vantex CVC with Oligon material does not contain chlorhexidine, the potential risk associated with chlorhexidine is avoided.

**VANTEX CVC WITH OLIGON MATERIAL – AVERAGE FLOW RATES IN ML/HR**

<table>
<thead>
<tr>
<th>7F DOUBLE LUMEN</th>
<th>16CM LONG CATHETER</th>
<th>20CM LONG CATHETER</th>
<th>GAUGE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal</td>
<td>3,781</td>
<td>3,481</td>
<td>16</td>
</tr>
<tr>
<td>Proximal</td>
<td>3,601</td>
<td>3,416</td>
<td>16</td>
</tr>
</tbody>
</table>

**7F TRIPLE LUMEN**

| Distal          | 3,593               | 3,535               | 16         |
| Medial          | 1,569               | 1,488               | 18         |
| Proximal        | 1,754               | 1,628               | 18         |

**8.5F DOUBLE LUMEN**

| Distal          | 6,190               | 5,900               | 14         |
| Proximal        | 4,964               | 4,594               | 15         |

**8.5F QUAD LUMEN**

| Distal          | 4,990               | 4,732               | 15         |
| Medial 1        | 1,544               | 1,394               | 18         |
| Medial 2        | 1,640               | 1,442               | 18         |
| Proximal        | 1,784               | 1,566               | 18         |

Flow rates shown using normal saline, room temperature, at 40" (101.6cm) head height
Multi-Med “High-Flow” Central Venous Catheters (CVCs) are constructed of soft polyurethane with a soft tip. Polyurethane material contributes to excellent handling, flexibility and kink-resistance. The Multi-Med CVC features optimized lumen and backform design, providing optimal flow characteristics, up to 50% faster than standard CVCs. Edwards CVCs are either 16cm or 20cm long to prevent the complications associated with over-insertion of the catheter, (i.e., perforation and cardiac tamponade.)
Central Venous Catheters (CVC) (continued)

**SINGLE-LUMEN**
Available as catheter only, basic sets, and expanded kit trays, with and without AMC THROMBOSHIELD, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>3F</td>
<td>20</td>
<td>13 cm</td>
</tr>
<tr>
<td>5F</td>
<td>16</td>
<td>20 cm</td>
</tr>
<tr>
<td>6F</td>
<td>14</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

**DOUBLE LUMEN**
Available as catheter only, basic sets, and expanded kit trays, with and without AMC THROMBOSHIELD, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7F</td>
<td>16/16</td>
<td>16 cm</td>
</tr>
<tr>
<td>7F</td>
<td>16/16</td>
<td>20 cm</td>
</tr>
<tr>
<td>8.5F</td>
<td>14/15</td>
<td>16 cm</td>
</tr>
<tr>
<td>8.5F</td>
<td>14/15</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

**TRIPLE LUMEN**
Available as catheter only, basic sets, and expanded kit trays, with and without AMC THROMBOSHIELD, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7F</td>
<td>16/18/18</td>
<td>16 cm</td>
</tr>
<tr>
<td>7F</td>
<td>16/18/18</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

**QUAD LUMEN**
Available as catheter only, basic sets, and expanded kit trays, with and without AMC THROMBOSHIELD, Interlink:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>GAUGE</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5F</td>
<td>15/18/18/18</td>
<td>16 cm</td>
</tr>
<tr>
<td>8.5F</td>
<td>15/18/18/18</td>
<td>20 cm</td>
</tr>
</tbody>
</table>
AMC THROMBOSHIELD is a proprietary antimicrobial heparin coating that is coated on both the inner and outer surfaces of the catheter. Decreased antimicrobial activity associated with AMC THROMBOSHIELD has been demonstrated using *in vitro* agar diffusion assays against the following organisms: *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Candida albicans*, *Escherichia coli*, *Serratia marcescens*, and *Acinetobacter calcoaceticus*. AMC THROMBOSHIELD decreases viable microbe count on surface of catheter during handling and placement.

**MULTI-MED CVC – AVERAGE FLOW RATES IN ML/HR**

<table>
<thead>
<tr>
<th>SINGLE-LUMEN</th>
<th>16CM LONG CATHETER</th>
<th>20CM LONG CATHETER</th>
<th>GAUGE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>7F DOUBLE LUMEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>3,608</td>
<td>3,292</td>
<td>16</td>
</tr>
<tr>
<td>Proximal</td>
<td>3,620</td>
<td>3,200</td>
<td>16</td>
</tr>
<tr>
<td><strong>7F TRIPLE LUMEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>3,510</td>
<td>3,160</td>
<td>16</td>
</tr>
<tr>
<td>Medial</td>
<td>1,500</td>
<td>1,300</td>
<td>18</td>
</tr>
<tr>
<td>Proximal</td>
<td>1,670</td>
<td>1,420</td>
<td>18</td>
</tr>
<tr>
<td><strong>8.5F DOUBLE LUMEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>6,126</td>
<td>5,886</td>
<td>14</td>
</tr>
<tr>
<td>Proximal</td>
<td>5,130</td>
<td>4,716</td>
<td>15</td>
</tr>
<tr>
<td><strong>8.5F QUAD LUMEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>4,812</td>
<td>4,564</td>
<td>15</td>
</tr>
<tr>
<td>Medial 1</td>
<td>1,538</td>
<td>1,349</td>
<td>18</td>
</tr>
<tr>
<td>Medial 2</td>
<td>1,623</td>
<td>1,412</td>
<td>18</td>
</tr>
<tr>
<td>Proximal</td>
<td>1,741</td>
<td>1,471</td>
<td>18</td>
</tr>
</tbody>
</table>

Flow rates shown using normal saline, room temperature, at 40" (101.6cm) head height.
### MULTI-MED CVC – AVERAGE LUMEN VOLUMES (ML)

<table>
<thead>
<tr>
<th>SINGLE-LUMEN</th>
<th>16CM</th>
<th>20CM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20ga</td>
<td>—</td>
<td>0.41</td>
</tr>
<tr>
<td>16ga</td>
<td>—</td>
<td>0.25</td>
</tr>
<tr>
<td>14ga</td>
<td>—</td>
<td>0.09</td>
</tr>
</tbody>
</table>

#### 7F DOUBLE LUMEN

<table>
<thead>
<tr>
<th></th>
<th>Distal</th>
<th>Proximal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.57</td>
<td>0.59</td>
<td>0.62</td>
</tr>
</tbody>
</table>

#### 7F TRIPLE LUMEN

<table>
<thead>
<tr>
<th></th>
<th>Distal</th>
<th>Medial</th>
<th>Proximal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.56</td>
<td>0.45</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>0.59</td>
<td>0.47</td>
<td>0.52</td>
<td></td>
</tr>
</tbody>
</table>

#### 8.5F DOUBLE LUMEN

<table>
<thead>
<tr>
<th></th>
<th>Distal</th>
<th>Proximal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.73</td>
<td>0.71</td>
<td>0.78</td>
</tr>
</tbody>
</table>

#### 8.5F QUAD LUMEN

<table>
<thead>
<tr>
<th></th>
<th>Distal</th>
<th>Medial 1</th>
<th>Medial 2</th>
<th>Proximal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.65</td>
<td>0.29</td>
<td>0.30</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>0.69</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Markings on the catheter body of Edwards Lifesciences’ CVCs (except for the single-lumen) are calibrated in 1 cm intervals, starting at 10 cm. The 15 cm depth is clearly marked. Guidewires are also marked at 10, 20 and 30 cm depths. These markings aid the clinician in correctly assessing the amount of catheter or guidewire inserted. Catheter depth should be routinely documented in the insertion and clinical notes.

### PORT COLOR DESIGNATION

<table>
<thead>
<tr>
<th>PORT</th>
<th>DOUBLE</th>
<th>TRIPLE</th>
<th>QUAD</th>
<th>AVA HF</th>
<th>AVA 3XI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal (1)</td>
<td>white</td>
<td>white</td>
<td>white</td>
<td>gray</td>
<td>white</td>
</tr>
<tr>
<td>Proximal (2)</td>
<td></td>
<td></td>
<td></td>
<td>blue</td>
<td></td>
</tr>
<tr>
<td>Medial (1)</td>
<td>blue</td>
<td>blue</td>
<td>blue</td>
<td>blue</td>
<td></td>
</tr>
<tr>
<td>Medial (2)</td>
<td></td>
<td></td>
<td></td>
<td>gray</td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
<td>brown</td>
</tr>
</tbody>
</table>
Practical Point
With Edwards’ devices, the distal lumen is always the largest. Look at the hub to see both catheter gauge and distance of lumen from tip.

SUTURE LOOP/BOX CLAMP
If desired, the optional suture loop/box clamp can be placed on the catheter and sutured to the skin.

- Place the optional suture loop onto the catheter by spreading the suture loop wings and pressing onto the catheter. (See Figure 1)
- Snap the box clamp over the optional suture loop to secure both components to the catheter. (See Figure 2)
- Suture the optional suture loop and box clamp together to the patient to prevent catheter migration. (See Figure 3)

Precaution: The box clamp must be removed from the catheter before attempting guidewire passage prior to catheter exchange.
Intro-Flex Percutaneous Sheath Introducers

**Important:** Insertion depths will vary according to the insertion site and the size of the patient.

1. Remove the guidewire and assure that venous blood can be freely aspirated through the distal lumen. Begin fluid infusion.

   For continuous infusion, attach infusion set luer connector to desired lumen hub and infuse per hospital protocol.

   **Precaution:** To avoid damage to the extension lumen, the slide clamp must be opened before infusing through the lumen.

2. Under continuous pressure monitoring, and fluoroscopy if desired, gently advance the catheter into the superior vena cava, stopping above the junction of the right atrium and the superior vena cava.

   **Precaution:** Positioning the distal tip of the catheter in the right atrium or ventricle is NOT recommended (see Complications).

3. Once in position, secure the catheter by suturing the suture wings to the skin. Note the approximate insertion depth of the catheter by observing the 5 cm depth markings on the catheter body.

4. If desired, the optional suture loop/box clamp can be placed on the catheter and sutured to the skin.
   a. Once the catheter has been inserted to the appropriate position and the guidewire has been removed, place the preslit optional suture loop onto the catheter by spreading the suture loop wings and pressing onto the catheter (see Figure 1).
   b. Snap the box clamp over the optional suture loop to secure both components to the catheter (see Figure 2).
   c. Suture the optional suture loop and box clamp together to the patient to prevent catheter migration (see Figure 3).

   Periodically check catheter placement to confirm tip has not migrated.

   **Precaution:** The box clamp must be removed from the catheter before attempting guidewire passage prior to catheter exchange.
Intro-Flex Percutaneous Sheath Introducers (continued)

5. Verify catheter tip position in the superior vena cava by chest X-ray film immediately after insertion.

Note: The chest X-ray film should confirm that the catheter tip is in the superior vena cava, above the superior vena cava and right atrial junction, with the catheter tip parallel to the vessel wall (Refs. 8, 11 & 16).

MAINTENANCE AND USE IN SITU

1. Adequate maintenance is required to avoid catheter occlusion. Keep pressure monitoring and infusion lumens patent by intermittent flush, continuous, slow infusion with heparinized saline solution, or use of a heparin lock using the provided injection caps or Interlink injection sites in conjunction with heparinized saline solution (Ref. 20).

To use injection caps:
   a. Disinfect injection caps before entry with syringe needle (see Complications).
   b. Use a small bore needle (22 gauge or smaller) to puncture and inject through the injection caps.

To use Interlink injection sites:
   a. Ensure that the injection sites are securely connected to the lumen hubs.
   b. Grasp finger flange to stabilize injection site (Figure 4).
   c. Swab septum with preferred antiseptic.
   d. Insert Interlink cannula, attach to an appropriate device directly through the center of the septum.

Precaution: If a conventional needle must be used, insert a small gauge needle into the perimeter of the septum to avoid fluid leakage while the needle is in place.

   e. Engage locking features if applicable.

2. For blood sampling, attach blood sampling device to desired lumen hub and draw blood sample per hospital protocol.
Intro-Flex Percutaneous Sheath Introducers (continued)

Intro-Flex Percutaneous Sheath Introducers feature the following design characteristics:

■ High infusion capability
■ Tapered tip to dilator interface
■ Choice of hemostasis valves
■ V-shaped sidearm
■ Optional infusion catheter with lock-in adapter
■ Optional obturator - short or long versions
■ Optional locking contamination shield

The Intro-Flex introducers are available with two valve options, either in an Automatic hemostasis valve, or Adjustable hemostasis valve that accommodates varying catheter sizes and helps prevent catheter migration. The v-shaped sidearm permits unobstructed path for fluid delivery, with or without a catheter in place. AMC THROMBOSHIELD coating is available on selected models.

A single-lumen infusion catheter is available for use with the Intro-Flex introducers to be placed through the hemostasis valve (after swabbing the valve with Betadine) to convert to a double lumen access. It has a lock-in adapter to safely secure the fitting between introducer and infusion catheter. The infusion catheter extends beyond the sheath to allow unobstructed fluid flow. An obturator is available to safely occlude the lumen as well as to prevent air entry when the catheter is not in use. The obturator is available in a short (cap) version or long 13cm option.

<table>
<thead>
<tr>
<th>FRENCH SIZE INTRODUCER</th>
<th>CATHETER SIZE (INFUSION CATHETER)</th>
<th>PAC SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5F</td>
<td>4F</td>
<td>4F</td>
</tr>
<tr>
<td>6F</td>
<td>5F</td>
<td>5F</td>
</tr>
<tr>
<td>7F</td>
<td>5F</td>
<td>6F</td>
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<tr>
<td>8F</td>
<td>7F</td>
<td>7F</td>
</tr>
<tr>
<td>8.5F</td>
<td>7F</td>
<td>7F - 7.5F</td>
</tr>
<tr>
<td>9F</td>
<td>7F</td>
<td>7.5F - 8F</td>
</tr>
</tbody>
</table>

**INSERTION**

- Use a single-lumen central venous catheter, unless multiple ports are essential for the management of the patient.
- In adults, consider use of a silver-impregnated collagen cuff or an antimicrobial- or antiseptic-impregnated central venous catheter if, after full adherence to other catheter infection control measures (e.g., maximal barrier precautions), there is still an unacceptably high rate of infection.
- Weigh the risk and benefits of placing a device at a recommended site to reduce infectious complications against the risk of mechanical complications (e.g., pneumothorax, subclavian artery puncture, subclavian vein laceration, hemotorax, thrombosis, air embolism, catheter misplacement).
- Use subclavian, rather than jugular or femoral, sites for central venous catheter placement unless medically contraindicated (e.g., coagulopathy, anatomic deformity).
- Use sterile technique, including a sterile gown and gloves, a mask, and a large sterile drape (i.e., maximal barrier precautions), for the insertion of central venous and arterial catheters. Use these precautions even if the catheter is inserted in the operating room.
- Wear non-latex or latex gloves when inserting an intravascular device as required by the Occupational Safety and Health Administration (OSHA) Bloodborne Pathogens Standard.
- Cleanse the skin site with an appropriate antiseptic, including 70% alcohol, 10% povidone-iodine, or 2% tincture of iodine, before catheter insertion. Allow the antiseptic to remain on the insertion site for an appropriate length of time before inserting the catheter.
- When tincture of iodine is used for skin antisepsis before catheter insertion, it should be removed with alcohol.
- Do not palpate the insertion site after the skin has been cleansed with antiseptic (this does not apply to maximum barrier precautions during which the operator is working in a sterile field).

■ Do not routinely replace non-tunneled central venous catheters as a method to prevent catheter-related infections.

■ Record the date and time of catheter insertion in an obvious location near the catheter-insertion site (e.g., on the dressing or on the bed).

GUIDEWIRE EXCHANGE

■ Use guidewire assisted catheter exchange to replace a malfunctioning catheter or to convert an existing catheter if there is no evidence of infection at the catheter site.

■ If catheter-related infection is suspected, but there is no evidence of local catheter-related infection (e.g., purulent drainage, erythema, tenderness), remove the existing catheter and insert a new catheter over a guidewire. Send the removed catheter for semiquantitative or quantitative culture. Leave the newly inserted catheter in place if the catheter culture result is negative. If the catheter culture indicates colonization or infection, remove the newly inserted catheter, and insert a new catheter at a different site.

■ Do not use guidewire assisted catheter exchange whenever catheter-related infection is documented. If the patient requires continued vascular access, remove the implicated catheter and replace it with another catheter at a different insertion site.

IV INFUSION

■ In general, administration sets include the area from the spike of tubing entering the fluid container to the hub of the vascular device. However, a short extension tube may be connected to the vascular device and may be considered a portion of the device to facilitate aseptic technique when changing administration sets. Replace extension tubing when the vascular device is replaced.

■ Wipe the catheter hub with an appropriate antiseptic before accessing the system.

■ Replace extension tubing when the vascular device is replaced.

■ Replace IV tubing, including piggyback tubing and stopcocks, no more frequently than at 72-hour intervals, unless clinically indicated.

- Replace tubing used to administer blood, blood products, or lipid emulsions within 24 hours of initiating the infusion.
- Clean injection ports with 70% alcohol or povidone-iodine before accessing the system.
- Do not use filters routinely for infection control purposes.

**TPN**

- Do not use single-lumen parenteral nutrition catheters for purposes other than hyperalimentation (e.g., administration of fluids, blood, or blood products).
- If a multi-lumen catheter is used to administer parenteral nutrition, designate one port for hyperalimentation. Do not use the designated hyperalimentation port for other purposes (e.g., administration of fluids, blood, or blood products).
- Complete infusions of lipid-containing parenteral nutrition fluids (e.g., 3-in-1 solutions) within 24 hours of hanging the fluid.
- When lipid emulsions are given alone, complete the infusion within 12 hours of hanging the emulsion.

**SITE CARE**

- Wash hands before and after palpating, inserting, replacing, or dressing any intravascular device.
- Wear non-latex or latex gloves when changing the dressings on intravascular devices.
- Palpate the catheter insertion site for tenderness daily through the intact dressing.
- Visually inspect the catheter site if the patient has development of tenderness at the insertion site, fever without obvious source, or symptoms of local or bloodstream infection.
- In patients who have large, bulky dressings that prevent palpation or direct visualization of the catheter insertion site, remove the dressing, visually inspect the catheter site at least daily, and apply a new dressing.
- Use either a sterile gauze or transparent dressing to cover the catheter site.

■ Replace catheter site dressings when the device is removed or replaced, or when the dressing becomes damp, loosened, or soiled. Change dressings more frequently in diaphoretic patients.

■ Avoid touch contamination of the catheter insertion site when the dressing is replaced.

■ Do not routinely apply antimicrobial ointment to central venous catheter insertion sites.

■ Do not apply organic solvents (e.g., acetone or ether) to the skin before insertion of parenteral nutrition catheters.

■ Replace catheter site dressings when the device is replaced, when the dressing becomes damp, loosened, or soiled, or when inspection of the site is necessary.

PRESSURE MONITORING SYSTEMS

■ Use disposable rather than reusable transducer assemblies whenever possible.

■ Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system, including the tubing, continuous flush device, and flush solution, at the time the transducer is replaced.

■ Keep sterile all components of the pressure monitoring circuit (including calibration devices and flush solution).

■ Minimize the number of manipulations and entries into the pressure monitoring system. Use a closed-flush (i.e., continuous flush), rather than an open system (i.e., one than requires a syringe and stopcock), to maintain patency of the pressure monitoring catheters. If stopcocks are used, treat them as a sterile field, and cover them with a cap or syringe when not in use.

■ When the pressure monitoring system is accessed through a rubber diaphragm rather than a stopcock, wipe the diaphragm with appropriate antiseptic before accessing the system.

■ Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit.

■ Do not routinely use pressure monitoring devices to obtain blood samples that do not require arterial blood.
MISCELLANEOUS

■ Conduct ongoing education and training of health care workers regarding indications for the use of and procedures for the insertion and maintenance of intravascular devices and appropriate infection control measures to prevent intravascular device-related infections. Audiovisuals can serve as a useful adjunct to standard educational efforts.

■ Designate trained personnel for the insertion and maintenance of intravascular devices.

NO RECOMMENDATION

■ For the use of sterile versus non-sterile clean gloves during dressing changes.

■ For removal of central catheters inserted under emergency conditions, where breaks in aseptic technique are likely to have occurred.

■ For obtaining blood samples for culture through central venous or central arterial lines.

■ For the frequency of routine replacement of dressings used on central catheter sites.

■ For frequency of replacement IV tubing used for intermittent infusions.

■ For the hang time of IV fluids, including non-lipid containing parenteral nutrition fluids.

■ For use, maintenance, or frequency of replacement of needleless IV devices.

These are selected guidelines only.
References


References (continued)


**AIR EMBOLISM**


**BLOOD DRAWS**


CARDIAC TAMPOONADE


**CATHETER EXCHANGE/REPLACEMENT**


**CENTRAL VENOUS PRESSURE (GENERAL)**


**CENTRAL VENOUS PRESSURE (TECHNICAL)**


**COATINGS**


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### COMPLICATIONS (GENERAL)


### DRESSINGS


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**STOPCOCK CONTAMINATION**


**SUMMARY ARTICLES**


Bibliography (continued)

THROMBOGENICITY/THROMBOSIS


TOTAL PARENTERAL NUTRITION


