ARROW

ARROW MULTI-LUMEN
MULTIPLE LUMEN

CENTRAL *venous* CATHETER

Nursing
Care
Guidelines

multi lumen

UNITED STATES
Arrow International, Inc.
2400 Bernville Road
Reading, PA 19605, USA
Phone: 610-378-0131
Toll-free: (800) 523-8446
Fax: 610-478-3199
Orders-only toll-free fax: (800) 343-2935
Email: Customer.Service@arrowintl.com

AFRICA
Arrow Africa (Pty) Ltd.
Cambridge Commercial Park
22 Witkoppen Road, Paulshof Extension
Sandton 2054, Republic of South Africa
Phone: (11) 807 4887
Fax: (11) 807 4994
Email: tlc@arrowafrica.co.za

AUSTRALASIA
Arrow International, Inc.
2400 Bernville Road
Reading, PA 19605, USA
Phone: 610-378-0131
Toll-free: (800) 233-3187
Fax: 610-374-5360
Email: australasia@arrowintl.com

CANADA
Arrow Medical Products, Ltd.
2300 Bristol Circle, Unit 1
Oakville, Ontario L6H 5S3
Phone: (905) 829-9473
Toll-free: (800) 387-7819
Fax: (905) 829-9414
Email: arrow.canada@arrowintl.com

CZECH REPUBLIC
Arrow International CR, a.s.
Pražská 209
500 04 Hradec Králové
Czech Republic
Phone: 049 575 9111
Fax: 049 575 9222
Email: czech.sales@arrowintl.com

EUROPEAN SALES OFFICE
Flevolaan 9A
NL 1382 JX
Weesp, The Netherlands
Phone: +31 294 29900
Fax: +31 294 414235
Email: europeansales@arrowintl.com

FRANCE
Arrow France S.A.
Atlantic Parc, « Les Pyramides » No. 11
Route de Pitoys, P.A. de Maignon
64600 Anglet, France
Phone: 05 59 31 34 90
Fax: 05 59 31 34 91
Email: arrow.sa@wanadoo.fr

GERMANY
Arrow Deutschland GmbH
Justus-von-Liebig-Strasse 2
D-85435 Erding, Germany
Phone: 08122 9820-0
Fax: 08122 40384
Email: service@arrow-deutschland.de

GREECE
Arrow Hellas A.E.E.
230 Kifissias Avenue
Halandri, 152 31
Athens, Greece
Phone: 6777717 / 6777311
Fax: 6777911
Email: arrowhel@hol.gr

HOLLAND
Arrow Holland Medical Products B.V.
Flevolaan 9A
NL 1382 JX
Weesp, The Netherlands
Phone: 294 280 620
Fax: 294 412 300
Email: c_service@arrow-holland.nl

INDIA
Arrow India
9 Demonte Street
Santhome, Mylapore
Chennai 600004
India
Phone: 44-495-6769
Fax: 44-495-6787
Email: arrowint@hotmail.com

JAPAN
Arrow Japan, Ltd.
Nagaoka Bldg.
3-16, Kita-Otsuka 3-chome
Toshima-ku, Tokyo 170-0004, Japan
Phone: 03-5974-1701
Fax: 03-5974-1845
Email: arrowjpn@courante.plala.or.jp

LATIN AMERICA
Arrow International, Inc.
2400 Bernville Road
Reading, PA 19605, USA
Phone: 610-378-0131
Toll-free: (800) 233-3187
Fax: 610-374-5360
Email: latinamerica@arrowintl.com

MEXICO
Arrow Internacional de Mexico S.A. de C.V.
Moliere No. 128, Col. Polanco
11560 Mexico City, Mexico
Phone: 5281-2291
Fax: 5282-1359
Email: arrowmex@mail.internet.com.mx

SLOVAKIA
Arrow Slovensko Piešťany s.r.o.
Valová 49
921 01 Piešťany, Slovakia
Phone/Fax: 0838/77 25428
Email: arrow@arrow.sk

SPAIN
Arrow Iberia S.A.
Avenida de Valgrande 14
28108 Alcobendas
Madrid, Spain
Phone: 916 621 267
Fax: 916 619 756
Email: arrow@arrow-iberia.es

"Without question, intravenous infusion therapy has become an indispensable therapeutic modality in present-day medicine. It has probably saved more lives than all the antibiotics ever developed."[1]

This very powerful statement made over a decade ago is still valid today as evidenced by the number of intravascular devices placed in patients annually. With the use of this technology has come a plethora of procedures and policies to guide its utilization. Today we find that many of these policies and procedures are not necessarily based on scientific research but rather on practitioner intuition and tradition. Review of the literature reveals very few definitive research studies on which to base protocols to support device care.

To assist practitioners who are striving to establish policies and procedures, Arrow International has compiled an extensive review of the central venous catheter literature. The intent of providing this information is to give guidance to you, the practitioner, in establishing catheter-related protocols. It is not meant to dictate nursing or medical practice.

The major areas of current concern have been addressed. Please bear in mind that as these words are written, research continues. The use of central venous catheters is an evolving science, and this review will continue to change as the body of knowledge expands.

These educational materials are shared with you, the practitioner, with hope that they will assist you in the pursuit of excellence in your practice.

Sincerely

Arrow International, Inc.

multiple *lumen* catheter

[1] Maki, DG. Preventing infection in intravenous therapy. *Anesth Analg*. January-February 1977;56:141.

types *of* catheters

Single-Lumen Catheters (SLC)

A SLC consists of a tube or lumen ending in a hub that can be capped and used for intermittent or continuous infusions of medication or fluid. The use of a single-lumen central venous catheter centers around the need for an infusion into a large central vein. Central venous catheterization is indicated when there are no peripheral sites available, when a viscous or hyperosmolar infusion is prescribed, or when a line is needed for OR support. This type of catheter may be used in an acute setting or to provide long-term access to a central vein for nutritional support, antibiotics, or chemotherapy. If the SLC is to be used for a prolonged period of time, the catheter may be "tunneled" on the chest for stabilization. Tunneling also reduces the risk of catheter-related infections.

Multiple-Lumen Catheters (MLC)

A MLC multiplies the advantages of a single-lumen catheter. The number of lumens within an MLC can vary from two to four and allows for many treatments to be performed through one venous access site. Therapy may be intermittent or constant. The multiple ports allow for administration of medications, blood infusion and sampling, fluid replacement, monitoring, and in certain catheters, visualization of cardio-vascular anatomy. Available literature shows that catheter design determines whether treatments that are incompatible may be given at the same time. Multiple-lumen catheters are found most frequently in the acute care setting; however, there are double-lumen catheters which have been developed for the long-term delivery of multiple treatments such as antibiotics and chemotherapy. As with SLC, these catheters must be placed in a central vein.

Peripherally Inserted Central Catheters (PICC)

PICCs are inserted into the arm and advanced until the end of the catheter is located in a central vein. The catheters contain one or two lumens and can be used to deliver continuous or intermittent therapy. PICCs can be used in an acute setting but have been most popular for long-term venous access to provide nutritional support, antibiotic therapy or chemotherapy. Because of the arm placement, specially-trained nurses, in addition to physicians, can insert the catheters.

Implantable Catheters

When there is a need for prolonged therapy, the central venous catheters of choice are those which can be implanted or tunneled under the skin. These specially adapted catheters are placed with the distal end positioned in a large vein. The proximal end of the catheter may consist of a hub and pigtails extending from the single or multiple lumens, or a self-sealing port which is placed under the skin. The tunneled lines have one or two lumens. They are sutured into a subcutaneous pocket on the chest or arm and constitute a completely closed system. Both catheter types may be used for the long-term infusions of antibiotics, TPN, chemotherapy or other fluids and medications.

Thermodilution Catheters

Thermodilution catheters, or pulmonary artery catheters, are used in an acute setting when an accurate assessment of pulmonary and cardiac status is necessary. The catheter contains multiple ports which can be used for infusions and monitoring. A balloon tip is incorporated into the catheter structure to facilitate, when inflated, wedge placement into a pulmonary artery to measure left-sided heart function. The catheter also has a temperature sensing device that can be used to measure cardiac output by the thermodilution method.

Hemodialysis Catheters

Hemodialysis catheters are single- or multiple-lumen catheters that provide temporary vascular access for hemodialysis until a permanent access is available or until another type of dialysis therapy is substituted. The multiple lumen catheters contain two large bore lumens that are connected to the dialysis machine to form a complete circuit for the removal and return of the patient's blood during treatment.

indications *for* central venous access

- Patients requiring multiple sites for IV access.

- Patients lacking useable peripheral IV sites.
- Patients requiring central venous pressure monitoring.
- Patients requiring total parenteral nutrition.
- Patients receiving incompatible medications.
- Patients requiring multiple infusions of fluids, medications, or chemotherapy.
- Patients subject to frequent blood sampling or receiving blood transfusions.
- Patients requiring a temporary access site for hemodialysis.
- Patients receiving infusions that are hypertonic, hyperosmolar or infusions that have divergent pH values.

catheter materials *and* properties

Intravascular catheters must be made of biocompatible materials that will withstand conditions within the vascular system without deteriorating or causing patient complications. Polymers, commonly known as plastics, have been used with much success. Certain properties are sought when developing a product for use within the vascular system, for example, thromboresistance, flexibility, smooth surface, lack of kink memory, and reasonable cost, to name a few. It is also important that the material does not leach off chemicals used in its manufacture. The six most common polymers used in vascular catheters are: polyethylene, fluoropolymer (Teflon®*), polyvinyl chloride (PVC), silicone, elastomeric hydrogel and polyurethane. [10-17]

Catheter Material	Advantages	Disadvantages
Polyethylene	High inherent strength	May be stiff
	Resistant to fats and oil	Exhibits kink memory
	High oxygen & carbon dioxide permeability	
	Overall good chemical resistance	
	Low moisture absorption	
Fluoropolymer (Teflon)	Resistant to chemicals	Exhibits kink memory
	Slippery surface due to low surface energy	High incidence of thrombosis
	May be stiff	
Polyvinyl chloride (PVC)	Stiff on insertion but softens within the body	High absorption of certain drugs
	High inherent strength, tough	High incidence of thrombosis
	Abrasion resistant	May leach out plasticizers
Elastomeric hydrogel	Predictable softening and size changes on contact with fluid	Contact with liquid prior to insertion prevents use
	Stiff for insertion and softens for biocompatibility	
Silicone	Most biocompatible	May knot
	Thromboresistant	Poor tolerance to pressure
	Slippery surface due to low surface energy	Some formulations not easily placed percutaneously
	Soft and pliant	
	Resistant to moisture, many chemicals	

Catheter Material	Advantages	Disadvantages
Polyurethane	High degree of biocompatibility	
	Good tensile strength	
	Wear resistant	
	Thromboresistant	
	Resistant to many chemicals	
	Kink resistant	
	Softens within the body	
	Able to use percutaneous technique	
	Thinner wall construction possible	

Arrow *multiple-lumen* design and specifications

Arrow multiple-lumen central venous catheters are radiopaque catheters available in a variety of lengths and French sizes ranging from 4 Fr. used in pediatrics to 12 Fr. used for hemodialysis or trauma. These catheters may have two, three or four separate lumens running the length of the catheter body. In all adult catheters the lumens exit at the distal end of the catheter through individual ports. The lumen exits are placed along the distal catheter body and are rotated 90° around the catheter circumference to minimize mixture of infusates. At the proximal end the lumens are connected to separate color-coded Luer-Lock extension lines or pigtails. Polyurethane, a compound which is sufficiently stiff to facilitate percutaneous insertion and softens inside the body, makes up the body of the catheters. To further reduce the chance for vessel trauma, Arrow multiple-lumen catheters have a Blue FlexTip® which is more pliant than the rest of the catheter. The distal end is tapered to form a dilating tip that will fit snugly over a .025" or .035" diameter spring wire guide.

The catheters are available in a variety of lengths with various lumen configurations as illustrated (refer to page 10). External markings on the body of the catheter are used to aid in proper anatomical placement of the catheter tip. The catheter body and pigtails converge at a blue triangular hub which is imprinted with information about the size, number of lumens and catheter length. The hub is used as a primary suture site for securing the catheter to the patient. A separate catheter clamp and fastener are provided for use on the catheter body as a secondary site for suturing if a sufficient length of the catheter remains exposed. Removable slide clamps are provided on the pigtails to aid in changing Luer-Lock injection caps and tubing. On 12 French catheters pinch clamps are provided for additional security.

Catheter Cross-Sections
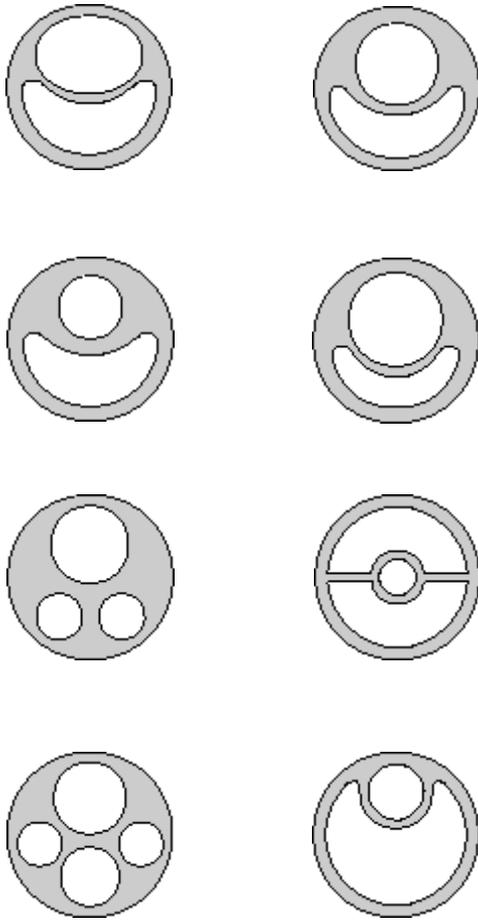
Priming Volumes and Flow Rates

The amount of space within a catheter lumen from the distal exit port to the end of the pigtail Luer-Lock hub is the catheter lumen priming volume. This volume is important for flushing/locking procedures. When used, the injection cap volumes must be added to the lumen volumes to determine the amount of fluid needed to completely fill capped lumens.

The volume of fluid that a catheter can deliver per unit of time is defined as the flow rate. The flow rate through a tube or catheter is dependent on several parameters which most importantly include internal (lumen) diameter, length of catheter, the change in pressure from inlet to outlet, and the viscosity of the fluid. Mathematically, the relationship is:

$$F = \frac{d^4 (P_1 - P_2)}{16\, \mu\, L}$$

Where: F = flow rate P_2 = outlet pressure

d = internal diameter   μ = fluid viscosity

P_1 = inlet pressure   L = length

In medical practice, a catheter is placed for many reasons with the most important reason being administration of fluids/flow. It is important to know how much flow can be infused through the catheter.

The flow rate is often incorrectly assumed to be proportional to the catheter's outside diameter (French scale) or gauge size. This assumption can lead to erroneous conclusions, as the equation (previous page) indicates. Further, this assumption becomes even more confusing when the catheter has multiple lumens. Typically, each individual lumen of a multiple lumen catheter is labeled with a nominal gauge size derived from the flow rate that a *typical single lumen* catheter of the *same length* would provide. In this situation, the gauge size does NOT relate to outside diameter or French scale measurement.

To eliminate any confusion, it is recommended that a clinician using a multiple lumen catheter know and consider the flow rates through each separate lumen.

The following table summarizes priming volumes and flow rates for a selection of Arrow products.

Flow Rates and Priming Volumes— Arrow Multi-Lumen Catheters

Description	Lumens	Priming Volume (cc)	Flow Rate (cc/hr) Gravity (standard tubing)
7 Fr. x 16cm (6")	2 Prox. (14 Ga.)	0.53	5630
	Distal (18 Ga.)	0.32	1460
7 Fr. x 16cm (6")	2 Prox. (16 Ga.)	0.38	3640
	Distal (16 Ga.)	0.40	3770
7 Fr. x 16cm (6")	3 Prox. (18 Ga.)	0.37	1900
	Med. (18 Ga.)	0.35	1800
	Distal (16 Ga.)	0.39	3380
7 Fr. x 20cm (8")	2 Prox. (16 Ga.)	0.45	3000
	Distal (16 Ga.)	0.47	3700
7 Fr. x 20cm (8")	2 Prox. (18 Ga.)	0.43	2190
	Distal (14 Ga.)	0.60	5590
7 Fr. x 20cm (8")	3 Prox. (18 Ga.)	0.39	1590
	Med. (18 Ga.)	0.39	1510
	Distal (16 Ga.)	0.44	3110
7 Fr. x 30cm (12")	3 Prox. (18 Ga.)	0.44	1090
	Med. (18 Ga.)	0.40	993
	Distal (16 Ga.)	0.49	2320
8 Fr. x 16cm (6")	2 Prox. (14 Ga.)	0.73	5770
	Distal (14 Ga.)	0.68	6200
8 Fr. x 20cm (8")	2 Prox. (14 Ga.)	0.79	4460
	Distal (14 Ga.)	0.75	5490
8.5 Fr. x 16cm (6")	4 Prox. (18 Ga.)	0.38	1840
	Med. 2 (18 Ga.)	0.36	1600
	Med. 1 (14 Ga.)	0.47	5410
	Distal (16 Ga.)	0.39	3180
8.5 Fr. x 20cm (8")	4 Prox. (18 Ga.)	0.41	1580
	Med. 2 (18 Ga.)	0.36	1430
	Med. 1 (14 Ga.)	0.54	5080
	Distal (16 Ga.)	0.43	2730
12 Fr. x 16cm (6")	2 Prox. (12 Ga.)	1.3	23700
	Distal (12 Ga.)	1.3	17400
12 Fr. x 20cm (8")	2 Prox. (12 Ga.)	1.40	19800
	Dist. (12 Ga.)	1.48	15500

Priming volumes are performed without the injection cap. Injection cap priming volume=0.17 cc.

Flow rates are performed with normal saline solution at room temperature and 40" head height. These rates represent approximate flow capabilities. Priming volumes and flow rates are printed on the package lidstock.

insertion *sites*

Multiple-lumen catheters are inserted into a large vein and threaded into the central venous system. To reduce the chance of complications, the central venous catheter tip should be placed in the superior vena cava[31-35,38-42] above its junction with the right atrium with the distal catheter parallel to the vessel wall[36,42]. For reference, the distal tip should be positioned at a level above either the azygos vein or the carina of the trachea whichever is better visualized. The insertion sites most frequently used are those listed below. (Refer to illustration.)

Site	Advantages	Disadvantages
Internal jugular	Large vessel Easy to locate Easy access Short, straight path to vena cava (right side) Low rate of complications	Uncomfortable for patient Hard to maintain dressing Close proximity to carotid artery Highest infection rate of insertion sites Problematic in patients with tracheotomies
External jugular	Easy to locate, visible	Difficult to cannulate (rolls, valves, tortuous path) Higher complication rate than other sites Hard to maintain dressing Uncomfortable for patient Problematic in patients with tracheotomies
Subclavian	Large vessel with high flow rate Lower infection rate Easy to dress and maintain Supra- or infraclavicular approaches Less restricting for patient	Lies close to the lung apex (pneumothorax risk) Close proximity to subclavian artery Difficult to control bleeding (noncompressable vessel)
Femoral	Easy access Large vessel Advantageous during resuscitation	Decreased patient mobility Increased rate of thrombosis, phlebitis and infection Risk of femoral artery puncture Dressings may be problematic
Brachial	Advantageous during resuscitation Easy access	Increased incidence of phlebitis Longer time for drugs to access central circulation Catheter tip movement related to arm movement
Umbilical	Easy access Accommodates fairly large catheter Rapid placement	Significant rate of complications
Basilic	Low incident of thoracic complication Direct route into central venous system with arm at 90 degree angle.	Increased incidence of phlebitis Catheter tip movement related to arm movement

Site	Advantages	Disadvantages
Cephalic	Easy access Low incidence of thoracic complications	More tortuous than basilic vein Increased incidence of phlebitis May be compressed with the clavicle by anatomical positioning Catheter tip movement related to arm movement

site *preparation*
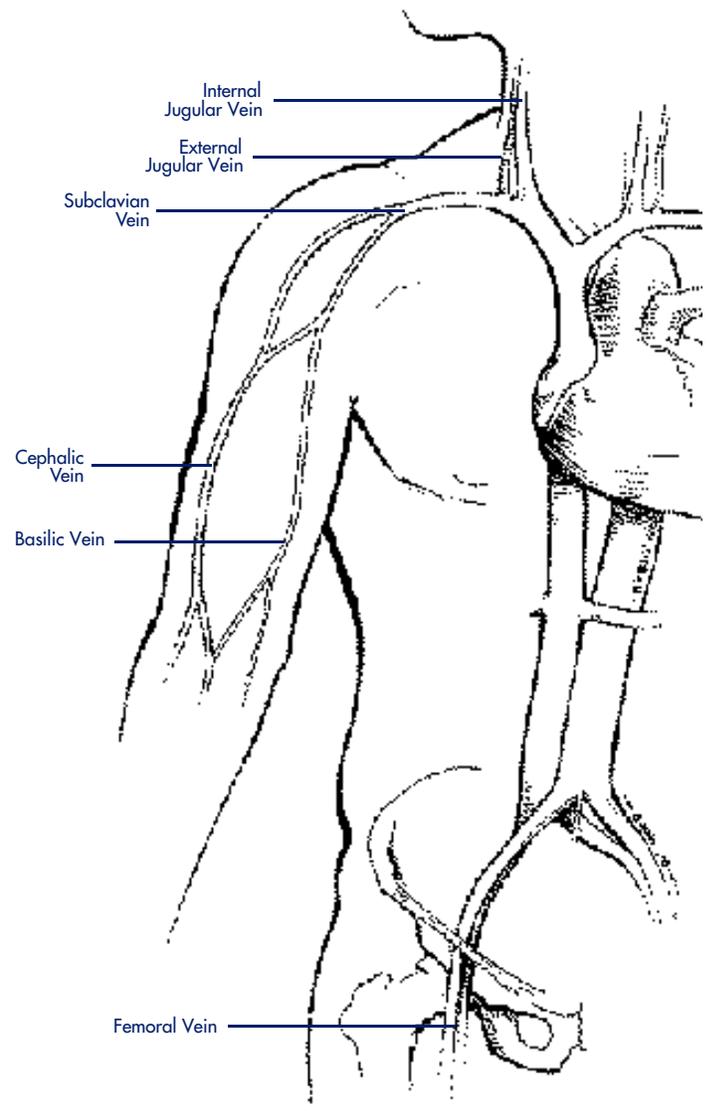
Standard procedures for skin preparation prior to the insertion of central venous catheters include the use of an antiseptic solution which kills or inhibits the growth of microorganisms. In this way the numbers of resident and transient organisms on the patient's skin are reduced. By reducing the patient's skin flora, the risks for developing an infection from the catheter insertion are decreased. As a rule, antiseptics are also included in routine follow-up care of the insertion site as designated within each institution. The choice of antiseptic should be made using available literature and information about the profile of patients served by the health care facility.

The three antiseptic solutions used most frequently are alcohol, iodine/iodophor, and chlorhexidine.[22]

Alcohol, Ethyl (ETOH)

Alcohol provides for the most rapid kill of microorganisms of the three agents listed. The organisms die because alcohol causes protein denaturation to occur. It is very effective against gram-negative and gram-positive bacteria, and also achieves high levels of kill for *Mycobacterium tuberculosis*, fungi and viruses. Alcohol is not effective against spores. Alcohol is also effective as a fat solvent.

To enable alcohol to denature protein it must be diluted with water. 70% ETOH is the solution of choice. Other concentrations are not as effective. To achieve maximum kill alcohol should be applied to the targeted insertion site with a vigorous rub lasting one minute during which the site is kept wet with solution. This is necessary since alcohol has no residual effects once it dries.

The disadvantages to using alcohol are that it is very drying to the skin and catheter materials with repeated application, and the solution is flammable.

Iodine/Iodophor Solutions

Iodine solutions achieve the kill of microorganisms through penetration of the cell wall and intracellular oxidation with resultant release of free iodine within the microbial contents. This probably disrupts protein and nucleic acid structure and synthesis. Iodine preparations are effective against gram-positive and gram-negative bacteria, *M. tuberculosis*, viruses and fungi, although prolonged contact may be needed to achieve kill against certain fungi and spores.

The iodine solutions used most frequently are iodophors, a combination of iodine and a solubizing agent or carrier which provides a sustained release of free iodine. The most common iodophor is povidone-iodine, a combination of iodine and polyvinylpyrolidine. The result of the iodophor combination is a reduction in toxicity and irritation to the skin. Because the iodine is released gradually, a contact time of two minutes is necessary to allow for optimum microbial kill. If adequate time is not routinely allowed for iodophor action, the use of tincture of iodine may be considered due to its more rapid action.[25]

A shortcoming of iodophors is the neutralization of their antimicrobial properties in the presence of proteinaceous materials such as blood and pus. There have also been reports of microbial growth in certain iodophor solutions prompting careful attention to the proper dilution.[23] The available concentrations are .5%, 2%, 7.5% and 10%.

Chlorhexidine

Chlorhexidine is a cationic biguanide that causes microbial death through cell wall disruption. It is very active against gram-positive organisms, gram-negative organisms and viruses, less active against fungi and minimally effective against *M. tuberculosis*. The major advantage of chlorhexidine is its ability to bind to skin protein leaving a residue with persistent antimicrobial effects for up to 6 hours after application. Organic material has minimal effect on the action of chlorhexidine. The strength of the solution which has been tested is 2%, and in at least one study this solution has been found superior to alcohol (70%) and povidone-iodine (10%) in preventing IV-related infections.[24]

Caution must be taken not to introduce chlorhexidine into the ear due to its known ototoxicity; otherwise, it has few side effects. Consideration must also be given to the fact that the action of chlorhexidine is pH dependent (5.5-7), and it can be inactivated by compounds found in hard water and soap.

Site Preparation Guidelines

- Do not remove hair at the site unless it interferes with dressing adherence. If necessary, clipping is preferable to shaving to avoid skin lacerations and disruption of the epidermal barrier to infection.[21]
- Check for patient sensitivity to the prepping solution by requesting known allergy information or testing on a small area of skin away from the proposed insertion site.
- Physically clean the skin prior to applying antiseptic solution and inserting the catheter. Care must be taken to remove all soap residue.
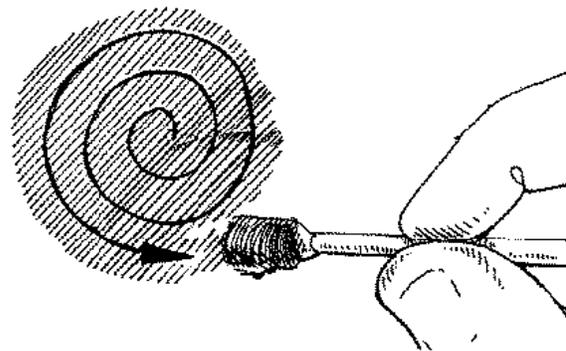
- Apply the antiseptic in a circular pattern beginning in the center of the proposed site and moving outward. (Refer to illustration.)
- Allow the antiseptic solution to air dry prior to inserting the catheter.

catheter *insertion*

Preparation

Gather the necessary supplies. It is permissible to set up the sterile field only if the procedure will follow immediately. Setting up prior to the procedure will compromise the sterility of the supplies.

Explain the procedure to the patient and obtain informed consent as required, if possible. Describe the Valsalva maneuver and the rationale for using it. To enhance venous return and increase intrathoracic pressure, place the patient in Trendelenburg position with a rolled towel between his/her shoulder blades. Warn the patient not to move. Describe the placement of sterile drapes and direct the patient not to disturb the sterile field.

Hands must be washed thoroughly prior to beginning the procedure. Use sterile technique and follow Universal Blood and Body Fluid Precautions for all catheter insertions. It is recommended that personnel directly involved in the catheter placement use maximal sterile barrier precautions to include mask, cap, sterile gloves, gown and a large sterile drape.[272]

Technique

The Seldinger or modified Seldinger method is the preferred technique used to insert a central venous catheter.[27,29] This percutaneous technique consists of: (1) locating the appropriate vein by using an introducer needle or a catheter over needle assembly; (2) introducing a spring-wire guide through the needle or catheter; and (3) threading a central venous catheter over the wire to the proper depth.

Percutaneous insertion of central venous catheters has become widely accepted for a number of reasons that include the speed of the procedure, preservation of vessel integrity, and a decrease in the risk of infection. Using a spring-wire guide also allows for the use of a small needle to ultimately place a much larger catheter.

Spring-wire guides must be strong but flexible enough to conform to vessel angles. The tips must be soft to prevent damage to the vessel wall. The end configurations may be straight, for direct pathways to the superior vena cava, or curved into a J-tip to facilitate passage through angles in vessels. Marked spring-wire guides aid practitioners in knowing the depth of the wire placement.
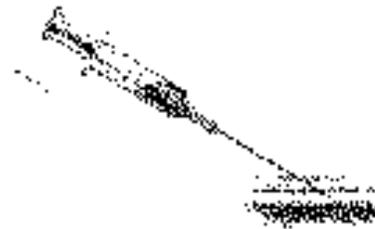
(1) locating the appropriate vein by using an introducer needle or a catheter over needle assembly;

(2) introducing a spring-wire guide through the needle or catheter;

(3) threading a central venous catheter over the wire to the proper depth.

Raulerson Syringe

The Arrow® Raulerson syringe is designed for use as an adjunct in the placement of a spring-wire guide using the Seldinger technique. The syringe is designed with a unique hollow plunger/barrel containing a patented valve system. The spring-wire guide is inserted into the plunger/barrel, through the introducer needle and into the vein. The benefits to using this syringe are the virtual elimination of the potential for air emboli, less vessel wall trauma, blood containment in the syringe barrel and stabilization of the needle bevel within the vessel lumen.

(1) locating the appropriate vein by using an introducer needle or a catheter over needle assembly;


(2) introducing a spring-wire guide through the needle or catheter;

(3) threading a central venous catheter over the wire to the proper depth.

Catheter Tip Placement

To reduce the risk of complications, e.g. cardiac tamponade, vessel wall perforation, or cardiac arrhythmias, the catheter tip must be located in the superior vena cava 3-4cm above the entry into the right atrium with the distal catheter positioned parallel to the vessel wall.[31-36,38,42]
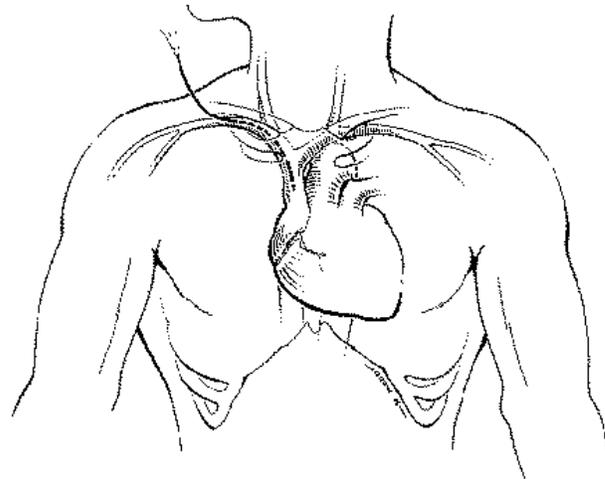
Prior to insertion, the external anatomy can be used to estimate the length of catheter needed for proper tip placement. During the procedure intravascular electrocardiography can be employed to determine the location of the tip within the central circulatory system.[37,39] This technique requires the use of an adapter, e.g. Arrow-Johans™ adapter, that is incorporated into the catheter set-up and is used to relay electrical impulses through a fluid-filled catheter lumen to an ECG monitor. By the P wave configuration of the ECG tracing the relative location of the catheter tip can be identified.

In addition to the above aids to provide correct catheter tip placement, a CHEST X-RAY MUST BE DONE immediately post-insertion.[31,32,34,38,40,41] An x-ray provides the only definitive evidence for catheter tip location. Until this verification is provided, fluids should be maintained at a keep-open rate.

Insertion Guidelines

• The person inserting the catheter should be trained and well-versed in anatomical landmarks, safe techniques and potential complications.

• The amount of catheter that has been inserted into the body must be documented. Centimeter markers on the external surface of the catheter body can be used, where provided. The marker position should be checked periodically and documented within the chart.

- A new approach, e.g. different site or different inserter, should be tried after 3-5 unsuccessful passes into one site.[30]
- Do not place the catheter into or allow it to remain within the right atrium or right ventricle.
- Do not apply excessive force in removing the spring-wire guide or catheter.
- Use Universal Blood and Body Fluid Precautions to avoid exposure to bloodborne pathogens.

product *instructions*

Central Venous Catheterization

must be performed by trained personnel well-versed in anatomical landmarks, safe technique, and potential complications.

Figure 1.

The pictogram (Figure 1) consisting of international symbols is used to further emphasize the need to place the tip of the catheter outside of the heart.

Insertion Procedure (using Raulerson Syringe)

Use Sterile Technique

1. **Precaution: Place patient in slight Trendelenburg position as tolerated to reduce the risk of air embolism. If femoral approach is used, place patient in supine position.**

2. Prep and drape puncture site as required.

3. Perform skin wheal with desired needle (25 Ga. or 22 Ga. needle).

4. Prepare the catheter for insertion by flushing each lumen and clamping or attaching the injection caps to the appropriate pigtails. Leave the distal pigtail uncapped for guide wire passage. **Warning: Do not cut the catheter to alter length.**

   Arrow UserGard® Needle-Free Injection Hub instructions:

   - Attach Luer end of UserGard® hub to syringe.
   - Prepare injection site with alcohol or Betadine per standard hospital protocol.
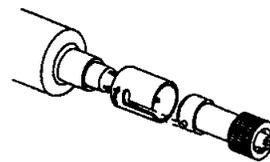

Figure 2.

- Remove red dust cap. Press UserGard® hub onto injection site and twist to lock on pin (see figure 2).
- Inject or withdraw fluid as required.

- Disengage UserGard® hub from injection site and discard. **Warning: To prevent possible air embolism, do not leave UserGard® Hub connected to injection site.** Single use only.

5. Insert introducer needle with attached Arrow® Raulerson Syringe into vein and aspirate. (If larger introducer needle is used, vessel may be prelocated with 22 Ga. locator needle and syringe). Remove locator needle.

   Alternate Technique:
   Catheter/needle may be used in the standard manner as alternative to introducer needle. If catheter/needle is used, Arrow® Raulerson Syringe will function as a standard syringe, but will not pass a spring-wire guide. If no free flow of venous blood is observed after needle is removed, attach syringe to the catheter and aspirate until good venous blood flow is established. **Precaution: The color of the blood aspirated is not always a reliable indicator of venous access.**[28] **Do not reinsert needle into introducer catheter.**

6. Because of the potential for inadvertent arterial placement, one of the following techniques should be utilized to verify venous access. Insert the fluid primed blunt tip transduction probe into the rear of the plunger and through the valves of the Raulerson Syringe. Observe for central venous placement via a wave form obtained by a calibrated pressure transducer (refer to figure 3). Remove transduction probe.
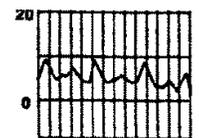

Figure 3.

   Alternate Technique:

   If hemodynamic monitoring equipment is not available to permit transducing a central venous wave form, check for pulsatile flow by either using the transduction probe to open the syringe valving system or by disconnecting the syringe from the needle. Pulsatile flow is usually an indicator of inadvertent arterial puncture.

7. Using the two-piece Arrow Advancer,™ advance spring-wire guide through syringe into vein. **Warning: Aspiration with spring-wir e guide in place will cause introduction of air into syringe. Precaution: To avoid leakage of blood from syringe cap do not reinfuse blood with spring-wire guide in place.**

Two-Piece Arrow Advancer™ Instruction:

• Remove protective cap.

• Using your thumb, straighten the "J" by retracting the spring-wire guide into the Arrow Advancer™ (refer to figure 4). When the tip is straightened, the spring-wire guide is ready for insertion. Centimeter marks are referenced from "J" end. One band indicates 10cm, two bands 20cm, and three bands 30cm.

Figure 4.

Introducing the Spring-Wire Guide:

• Place the tip of the Arrow Advancer™—with "J" retracted—into the hole in the rear of the Raulerson syringe plunger (refer to figure 5).

Figure 5.

• Advance spring-wire guide into the syringe approximately 10cm until it passes through the valves.

• Lift your thumb and pull the Arrow Advancer™ approximately 4cm to 8cm away from the syringe. Lower thumb onto the Arrow Advancer™ and while maintaining a firm grip on the spring-wire guide, push the assembly into the syringe barrel to further advance the spring-wire guide. Continue until spring-wire guide reaches desired depth (refer to figure 6).

Figure 6.

Alternate Technique:

If a simple straightening tube is preferred, the straightening tube portion of the Arrow Advancer™ can be disconnected from the unit and used separately. Separate the Arrow Advancer™ tip or straightening tube from the blue Arrow Advancer™ unit. If the "J" tip portion of the spring-wire guide is used, prepare for insertion by sliding the plastic tube over the "J" to straighten. The spring-wire guide should then be advanced in the routine fashion to the desired depth.

8. Advance guide wire until triple band mark reaches rear of syringe plunger. Advancement of "J" tip may require a gentle rotating motion. **Warning: Do not cut spring-wire guide to alter length. Do not withdraw spring-wire guide against needle bevel to avoid possible severing or damaging of spring-wire guide.**

9. Hold spring-wire guide in place and remove introducer needle and Raulerson syringe (or catheter). **Precaution: Maintain firm grip on spring-wire guide at all times.** Use centimeter markings on spring-wire guide to adjust indwelling length according to desired depth of indwelling catheter placement.

10. Enlarge cutaneous puncture site with cutting edge of scalpel positioned away from the spring-wire guide. **Precaution: Do not cut guide wire.** Use vessel dilator to enlarge site as required. **Warning: Do not leave vessel dilator in place as an indwelling catheter to avoid possible vessel wall perforation.**

11. Thread tip of multiple lumen catheter over spring-wire guide. Sufficient guide wire length must remain exposed at hub end of catheter to maintain a firm grip on guide wire. Grasping near skin, advance catheter into vein with slight twisting motion. **Precaution: Catheter clamp and fastener must not be attached to catheter until spring-wire guide is removed.**

12. Using cm marks on catheter as positioning reference points, advance catheter to final indwelling position.

13. Hold catheter at desired depth and remove spring-wire guide. The Arrow catheter included in this product has been designed to freely pass over the spring-wire guide. If resistance is encountered when a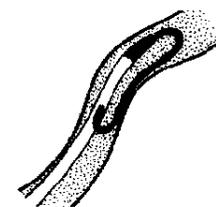ttempting to remove the spring-wire guide after catheter placement, the spring-wire may be kinked about the tip of the catheter within the vessel (refer to figure 7). In this circumstance, pulling back on the spring-wire guide may result in undue force being applied resulting in spring-wire guide breakage. If resistance is encountered, withdraw the catheter relative to the spring-wire guide about 2-3cm and attempt to remove the spring-wire guide. If resistance is again encountered remove the spring-wire guide and catheter simultaneously.

Figure 7.

Warning: Although the incidence of spring-wire guide failure is extremely low, the practitioner should be aware of the potential for breakage if undue force is applied to the wire.

14. Verify that the entire spring-wire guide is intact upon removal.

15. Check lumen placement by attaching a syringe to each pigtail and aspirate until free flow of venous blood is observed. Connect all pigtails to appropriate Luer-Lock line(s) as required. Unused port(s) may be "locked" through injection cap(s) using standard hospital protocol. Slide clamps are provided on pigtails to occlude flow through each lumen during line and injection cap changes. **Precaution: To avoid damage to pigtails from excessive pressure, each clamp must be opened prior to infusing through that lumen.**

16. Secure and dress catheter temporarily.

17. Verify catheter tip position by chest x-ray immediately after placement. **Precaution: X-ray exam must show the catheter located in the right side of the mediastinum in the SVC with the distal end of the catheter parallel to the vena cava wall and its distal tip positioned at a level above either the azygos vein or the carina of the trachea, whichever is better visualized.** If the catheter tip is malpositioned, reposition and reverify.

18. Secure the catheter to patient. Use triangular juncture hub with integral suture ring and side wings as primary suture site. In kits where provided, the catheter clamp and fastener should be utilized as a secondary suture site as necessary. **Precaution: Do not suture directly to the out-side diameter of the catheter to avoid cutting or damaging the catheter or impeding catheter flow.**

Catheter Clamp and Fastener Instructions:

- After spring-wire guide has been removed and the necessary lines have been connected or locked, spread wings of rubber clamp and position on catheter as required to ensure proper tip location (refer to figure 8).

Figure 8.

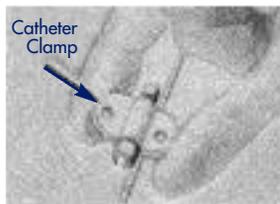- Snap rigid fastener onto catheter clamp (refer to figure 9).
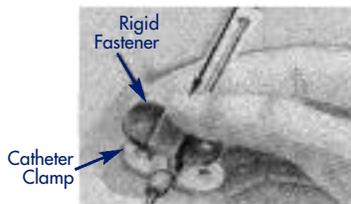

Figure 9.

- Secure catheter to patient by suturing the catheter clamp and fastener together to the skin, using side wings to prevent catheter migration (refer to figure 10).
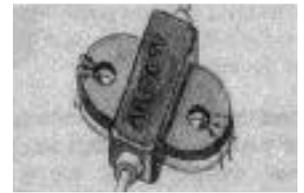

Figure 10.

19. Dress puncture site per hospital protocol. **Precaution: Maintain the insertion site with regular meticulous redressing using aseptic technique.**

20. Record on the patient's chart the indwelling catheter length as to centimeter markings on catheter where it enters the skin. Frequent visual reassessment should be made to ensure that the catheter has not moved.

Central Venous Catheterization must be
performed by trained personnel well versed in anatomical land-marks, safe technique, and potential complications.

Insertion Procedure (without Raulerson Syringe)

Use Sterile Technique.

1. **Precaution: Place patient in slight Trendelenburg position as tolerated to reduce the risk of air embolism. If femoral approach is used, place patient in supine position.**

2. Prep and drape puncture site as required.

3. Perform skin wheal with desired needle (25 Ga. or 22 Ga. needle).

4. Prepare catheter for insertion by flushing each lumen and clamping or attaching the injection caps to the appropriate pigtails. Leave the distal pigtail uncapped for guide wire passage. **Warning: Do not cut the catheter to alter length.**

Arrow UserGard® Needle-Free Injection Hub instructions:

- Attach Luer end of UserGard® hub to syringe.

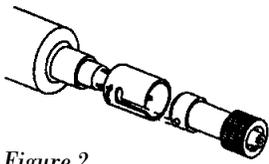- Prepare injection site with alcohol or Betadine per standard hospital protocol.

Figure 2.

- Remove red dust cap. Press UserGard® hub onto injection site and twist to lock on pin (see figure 2).

- Inject or withdraw fluid as required.

- Disengage UserGard® hub from injection site and discard. **Warning: To prevent possible air embolism, do not leave UserGard® Hub connected to injection site.** Single use only.

5. Locate central vein with a 22 Ga. needle and syringe.

6. Insert introducer catheter/needle with attached syringe into vein beside locator needle and aspirate. Remove locator needle. If no free flow of venous blood is observed after needle is removed, attach syringe to the catheter and aspirate until good venous blood flow is established. **Precaution: The color of the blood aspirated is not always a reliable indicator of venous access.** [28] **Do not reinsert needle into introducer catheter** .

   Because of the potential for inadvertent arterial placement, verify venous access via a wave form obtained by a calibrated pressure transducer (refer to figure 3, page 29).[2]
   - If hemodynamic monitoring equipment is not available to permit transducing a central venous wave form, disconnect the syringe from the needle and check for pulsatile flow. Pulsatile flow is usually an indicator of inadvertent arterial puncture.

Alternate Technique:
   Introducer needle may be used in the standard manner as alternative to catheter/needle assembly.

7. Insert desired tip of spring-wire guide through introducer needle or catheter into vein. If the "J" tip portion of the spring-wire guide is used, prepare for insertion by sliding the plastic tube over the "J" to straighten. The spring-wire guide should then be advanced in the routine fashion to the desired depth. Advancement of "J" tip may require a gentle rotating motion. **Warning: Do not cut spring-wire guide to alter length. Do not withdraw spring-wire guide against needle bevel to avoid possible severing or damaging of spring-wire guide.**

8. Hold spring-wire guide in place and remove introducer needle or catheter. **Precaution: Maintain firm grip on spring-wir e guide at all times.**

9. Enlarge cutaneous puncture site with cutting edge of scalpel positioned away from the spring-wire guide. **Precaution: Do not cut guide wire.** Use vessel dilator to enlarge site as required. **Warning: Do not leave vessel dilator in place as an indwelling catheter to avoid possible vessel wall perforation.**

10. Thread tip of multiple lumen catheter over spring-wire guide. Sufficient guide wire length must remain exposed at hub end of catheter to maintain a firm grip on guide wire. Grasping near skin, advance catheter into vein with a slight twisting motion.

    Precaution: Catheter clamp and fastener must not be attached to catheter until spring-wire guide is removed.

11. Using cm marks on catheter as positioning reference points, advance catheter to final indwelling position.

12. Hold catheter at desired depth and remove spring-wire guide. The Arrow catheter included in this product has been designed to freely pass over the spring-wire guide. If resistance is encountered when attempting to remove the spring-wire guide after catheter placement, the spring-wire guide may be kinked about the tip of the catheter within the vessel (refer to figure 7, page 33). In this circumstance, pulling back on the spring-wire guide may result in undue force being applied resulting in spring-wire breakage. If resistance is encountered, withdraw the catheter relative to the spring-wire guide about 2-3cm and attempt to remove the spring-wire guide. If resistance is again encountered remove the spring-wire guide and catheter simultaneously. **Warning: Although the incidence of spring-wire guide failure is extremely low, the practitioner should be aware of the potential for breakage if undue force is applied to the wire.**

13. Verify that the entire spring-wire guide is intact upon removal.

14. Check lumen placement by attaching a syringe to each pigtail and aspirating until free flow of venous blood is observed. Connect all pigtails to appropriate Luer-Lock line(s) as required. Unused port(s) may be "locked" through injection cap(s) using standard hospital protocol. Slide clamps are provided on pigtails to occlude flow through each lumen during line and injection cap changes.

Precaution: To avoid damage to pigtails from excessive pressure, each clamp must be opened prior to infusing through that lumen.

15. Secure and dress catheter temporarily.

16. Verify catheter tip position by chest x-ray immediately after placement. Precaution: X-ray exam must show the catheter located in the right side of the mediastinum in the SVC with the distal end of the catheter parallel to the vena cava wall and its distal tip positioned at a level above either the azygos vein or the carina of the trachea, whichever is better visualized. If the catheter tip is malpositioned, reposition and re-verify.

17. Secure catheter to patient. Use triangular juncture hub with integral suture ring and side wings as primary suture site. In kits where provided, the catheter clamp and fastener should be utilized as a secondary suture site as necessary. Precaution: Do not suture directly to the outside diameter of the catheter to avoid cutting or damaging the catheter or impeding catheter flow .

    Catheter Clamp and Fastener Instructions:
    • After spring-wire guide has been removed and the necessary lines have been connected, spread wings of rubber clamp and position on catheter as required to ensure proper tip location (refer to figure 8, page 35).
    • Snap rigid fastener onto catheter clamp (refer to figure 9, page 35).
    • Secure catheter to patient by suturing the catheter clamp and fastener together to the skin, using side wings to prevent catheter migration (refer to figure 10, page 36).

18. Dress puncture site per hospital protocol. Precaution: Maintain the insertion site with regular meticulous redressing using aseptic technique.

19. Record on the patient's chart the indwelling catheter length as to centimeter markings on the catheter where it enters the skin. Frequent visual reassessment should be made to ensure that the catheter has not moved.

port *designation*

The ports of a multiple lumen central venous catheter should be labeled for designated use, and the information should be entered into the chart and onto the patient's Kardex or information sheet. The reason for port designation is to ensure uniform use of the catheter lumens by health care personnel who are providing treatments through the catheter.

There is a lack of scientific data to support many of the designation protocols currently in use. Most choices have been made using deductive reasoning. For example, the distal port is usually used for central venous pressure monitoring. The reasons given for this choice are that the distal lumen is the largest lumen and it is closest to the heart, but theoretically other lumens could be used provided they exit within the central venous system, i.e. the superior or inferior vena cava (See Monitoring section).

The proximal port is often designated for blood sampling. This choice is made because the rapid flow of blood within the large central vein quickly carries the infusates from the more distal lumens, that might affect laboratory tests, away from the proximal sampling port. As an additional safeguard against erroneous lab results, it is recommended that all other infusions be turned off prior to blood sampling. (See Blood Sampling in Catheter Maintenance Section).

Another designation that has gained widespread acceptance is the need to reserve one lumen exclusively for total parenteral nutrition (TPN). The rationale for this designation is the prevention of catheter-related infections. When using a triple lumen catheter, the middle port is often chosen. The following designations are examples for port usage and do not represent the only way the lumens can be used:

Proximal:	Blood Sampling
	Medications
	Blood Administration
Medial:	Total Parenteral Nutrition
	Medications (only if TPN use is not anticipated)
Distal:	CVP Monitoring
	Blood Administration
	High Volume or Viscous Fluids
	Colloids
	Medication
4th Lumen:	Infusion
	Medication

More scientific study is needed to further define the scope of port designation. With the knowledge that is available, the most important issue is that the designations must be uniform when used by all persons involved in patient care.

complications

It is estimated that approximately 10% of patients who have a central line placed will experience a complication secondary to the catheter insertion or use.[44] Whether or not complications occur depends upon a number of factors including the experience of the inserting physician,[30,51] anatomical distortion at the potential insertion site, and the patient's condition. Each site that can be used, e.g. subclavian vs. internal jugular vs. femoral, has certain risks involved due to the normal body anatomy in that area.[19,20] Other individual patient factors are also important, such as underlying disease, tolerance of Trendelenburg position, laboratory levels associated with bleeding, and the patient's mental or emotional status to mention a few.

The complications are generally divided into two groups, immediate or delayed, dependent upon the time they appear in relation to the catheter insertion. Immediate complications are usually associated with catheter placement; however, some may develop later under certain circumstances. Delayed complications are manifested after the catheter has been indwelling for a period of time. Only the most frequently encountered complications will be included in this section.

Immediate	Delayed
venous air embolism	catheter-related infection
cardiac tamponade	catheter-related thrombosis
catheter embolus/rupture	hydrothorax/vessel erosion
arterial puncture	
cardiac dysrhythmia	
nerve injury	
catheter malposition	
pneumothorax, hemothorax	

Immediate Complications

Venous Air Embolism –A bolus of air within the venous circulation.

Pathophysiology — The pressures within the central venous circulation are in direct accord with the pressures involved with respiration. On expiration the intrathoracic and intravenous pressures are greater than the atmospheric pressure making it less likely that air would enter the venous system. On inspiration the opposite is true and, in accord with equalizing pressures, air is sucked through an opening into the venous system. The air proceeds as a bolus into the heart where it usually lodges against the pulmonic valve and blocks the pulmonary blood flow. With the increasing force of the pumping right ventricle, the air bolus may break up into smaller bubbles that enter the pulmonary circulation. This causes more blood obstruction which leads to localized tissue hypoxia, decreased cardiac output, and a resultant generalized decrease in tissue perfusion. Without intervention the condition rapidly progresses to shock and death. The mortality rate ranges from 29-50%.[73]

Factors that affect the severity of the condition are the volume of air that enters the circulation, the rate of the air entry, patient hydration status, and the position of the patient. If the air enters rapidly, it will more likely form a bolus that blocks blood circulation as opposed to the dispersed pattern which results with slower air entry. It is estimated that symptoms will appear if air enters the venous system at 20ml/sec., and death can occur at 75-150ml/sec.[59,70] When looking at these numbers, the possibility of this amount of air influx seems unlikely; however, it has been shown that 100ml/sec. flow of air can occur through a 14 ga. needle with a pressure gradient of 5cm H_2O.[59,70] Concerning volume, 70-300cc may be fatal.[72] The symptoms will also be more severe when the patient is in an upright position, is dehydrated or hypovolemic.

Occurrence/ Predisposing Factors
- at insertion of CVC
- with break in catheter connection
- with open damage to hub or catheter body
- after catheter removal due to remaining subcutaneous track[58,62,70,73,74]
- if IV fluids run dry
- if a percutaneous sheath remains in place without catheter or obturator[60]
- during neurosurgical and head/neck surgical procedures in sitting position[66]

Signs, Symptoms & Data	• may be nonspecific
	• sudden unexplained hypoxia or cardiovascular collapse
	• pulmonary: sucking sound on inspiration, pulmonary hypertension, respiratory distress, tachypnea progressing to apnea
	• cardiovascular: millwheel murmur over precordium, increased pulmonary artery pressure, jugular vein distention, decreased cardiac output, chest pain, hypotension, tachycardia, increased central venous pressure.
	• neurological: anxiety, hypoxic symptoms, change in mental status, dizziness, confusion, syncope, seizures, coma
Interventions	• prompt recognition and immediate action
	• access CVC line and correct any problems
	• place patient on left side in steep Trendelenburg
	• administer 100% oxygen
	• notify physician
	• chest massage to displace air bolus from pulmonic valve[55,64,65,73]
	• catheter aspiration of air from right ventricle
	• hyperbaric chamber
Prevention	• place patient in Trendelenburg or flat position for catheter insertion and removal
	• have patient use Valsalva maneuver or hold breath during injection hub or tubing changes
	• use Luer-Lock connection, tape
	• apply occlusive dressing after CVC removal (24-72 hours)[58,62,73]
	• use Raulerson syringe or occlude open hub with finger prior to guide wire insertion
	• occlude all ports of MLC
	• flush air out of all catheter ports
	• anchor catheter securely
	• use slide clamps for tubing change
	• turn stopcocks to a position that closes the line to air
	• give sedation, if necessary
	• patient teaching
	• provide adequate hydration
	• check all catheter connections and catheter integrity regularly

<u>Cardiac</u> <u>Tamponade</u>	A syndrome of circulatory abnormalities caused by excess fluid in the pericardial space.
Pathophysiology	The pericardial sac normally holds 10-20ml of fluid which serves to cushion and protect the heart. When excess fluid is introduced the pressure in the pericardial space increases and impairs the filling of the heart during diastole. As the pressure builds, cardiac output is decreased with detrimental effects on the systemic circulation. If left unchecked, the condition will lead to total circulatory collapse, shock, and death.
	Cardiac tamponade may be acute or long term. Symptomatology depends on the rate of fluid accumulation, the amount of fluid build-up and the pericardial compliance. In acute tamponade the fluid accumulation occurs rapidly and the pericardium remains inelastic and restraining. In this setting 100-300ml of excess fluid is potentially fatal.[83,90]
	Tamponade that develops over a longer period of time is due to a slow fluid accumulation which provides time for pericardial compliance. It is not unusual to find an accumulation of 1000-2000ml of fluid in this setting.[83,90]
	A majority of central venous catheter-induced cases of tamponade reported in the literature have been acute in origin and represent a gravely emergent complication with a mortality rate of 70-85% often due to a delay in diagnosis.[84] The fluid accumulation is usually due to a catheter perforation of the superior vena cava, right atrium, or right ventricle.
Occurrence/ Predisposing Factors	• catheter in right atrium or right ventricle
	• catheter migration with arm or neck motion, depends on the insertion site
	• catheter not parallel to the vessel wall
	• catheter made of "stiff" material or dilator remains indwelling[87]
	• left-sided insertion[88]

Signs, Symptoms & Data	• acutely ill appearance
	• may mimic other conditions
	• all signs and symptoms may not be present or detected
	• acute presentation is a true emergency
	• cardiovascular: tachycardia, hypotension, distant or muffled heart sounds, chest or epigastric pain, venous engorgement of neck and face, thready or absent peripheral pulses, dusky or pale nail beds, pericardial friction rub, cyanosis, narrow arterial pulse pressure, elevated CVP, ECG abnormalities (low voltage, ST changes, electrical alternans), decreased cardiac output, cardiac arrest, Beck's triad = increased CVP + decreased arterial pressure + quiet heart
	• nausea and abdominal pain
	• respiratory: dyspnea, tachypnea, short of breath, pulsus paradoxus, hypoxemia, respiratory alkalosis,Kussmaul's sign
	• neurological: restlessness, diaphoresis, confusion decreased level of consciousness, coma
	• non-acute diagnostics:
	  echocardiogram - demonstrates echo-free space separating pericardium from heart wall
	  chest x-ray - demonstrates cardiomegaly, large cardiac silhouette or "water bottle" heart associated with massive pericardial effusion
	  ECG - S-T changes, low voltages, electrical alternans
	  CAT, MRI

Interventions	• prompt recognition and immediate action • notify physician • lower infusion bag to facilitate gravity drainage[75,77,78] • physician aspiration through catheter • pericardiocentesis • thoracostomy
Prevention	• be aware of tamponade potential • avoid using "stiff" catheters • do not use a beveled catheter • use soft guide wire, J tip • perform preinsertion anatomic measurement • verify blood return from all ports after insertion and recheck regularly

• secure catheter with sutures and tape
• document length of catheter inserted and routinely check for catheter migration
• verify placement of catheter tip in superior vena cava by chest x-ray immediately after insertion and before infusion, including catheters changed over a guide wire[31,32,34,38,40,41,85]
• periodically reassess tip position by chest x-ray
• remove catheter when no longer needed

Catheter Embolus/ Rupture

Pathophysiology	At the time of insertion or sometime after the multiple lumen catheter is indwelling, physical damage to the catheter body can occur. During insertion the catheter can be damaged by exposure to the sharp edge of the introducer needle. The catheter can be nicked or a portion can be sheared off and enter the bloodstream or adjacent structures as an embolic fragment. The final resting location of the fragment will determine the severity of the patient's symptoms. A portion of the catheter can also be broken off if extreme pressure is exerted and the catheter is improperly secured. "Softer" catheters can be damaged when excessive force is applied at the time of irrigation. The force can rupture the catheter body and the resultant catheter dysfunction will be related to the location of the rupture. The rupture can also be a function of the catheter insertion site if it is "pinched" between the clavicle and the first rib due to subclavian placement.
Occurrence/ Predisposing Factors	• use of syringe smaller than 10cc to irrigate or declot a blocked catheter[92] • patient with altered mental status • insertion technique - catheter or spring-wire guide pulled back against the needle bevel[93,94] • use of scissors or other sharp instruments during dressing change or reinsertion over a guide wire • poorly secured catheter • forceful irrigation • "soft" catheter material

Signs, Symptoms or Data	• fluid leakage from the insertion site
	• cardiopulmonary signs and symptoms, e.g., palpitations, shortness of breath
	• dysrhythmias on ECG
	• catheter malfunction
Interventions	• catheter removal or guide wire exchange
	• catheter fragment retrieval (hooked catheters, wire loops, stone baskets, endoscopic forceps, surgery)
Prevention	• only advance the catheter forward through the introducer needle
	• if the insertion procedure is unsuccessful, withdraw the catheter and needle as one unit
	• secure catheter to the patient
	• take measures to prevent the patient from forcefully removing the catheter
	• use a 10cc syringe or larger to irrigate or declot an occluded catheter[92]

Arterial Puncture

Pathophysiology	Due to the anatomical proximity of arteries to veins at certain insertion sites, it is possible that an artery can be entered, transected or lacerated during the insertion procedure. The sites where this complication occurs most frequently are the subclavian, the internal jugular and the femoral veins. Many arterial punctures are uncomplicated; however, a hematoma can develop that can represent significant blood loss from circulation and might impinge upon other anatomical structures.
Occurrence/ Predisposing Factors	• insertion site
	• patient dehydration
	• insertion technique
	• inserter experience
Signs, Symptoms & Data	• bright red blood in syringe
	Note: the color of the blood may not be a reliable indicator dependent upon the patient's conditions[28]
	• pulsatile blood flow
	• hematoma development
Intervention	• observe for bright red, pulsatile blood flow and if noted, remove needle immediately, apply pressure
	• direct pressure for 5-10 minutes

	• pressure dressing
	• monitor vital signs
	• x-ray to determine extent of blood collection
	• comparative blood gases
Prevention	• knowledge about potential for this complication
	• ECG confirmation of venous placement using pressure transducer
	• use of small locator needle to find vessel[95]

Dysrhythmias

Pathophysiology	When the multiple lumen catheter or guide wire is advanced too far and enters the heart, the myocardium may be stimulated and result in an abnormal cardiac rhythm. The dysrhythmias may be atrial, ventricular or in the form of a conduction abnormality, i.e., a bundle branch block. Another mechanism for producing a dysrhythmia is the stimulation of the carotid sinus during an internal jugular insertion attempt. In both cases the change in cardiac rhythm may be detrimental to the patient. The rhythm abnormality will usually disappear when the offending stimulation is discontinued. If, due to guide wire or catheter-induced damage, a conduction pathway is disturbed, the conduction abnormality may be permanent. An extremely difficult situation might arise if the patient already has an existing left bundle branch block. A right bundle branch block induced by a catheter or guide wire may lead to complete heart block and severe patient compromise.[96]
Occurrence/ Predisposing Factors	• a difficult internal jugular insertion (possible carotid sinus stimulation)
	• antecubital insertion (catheter migration into the heart with arm movement)
	• improper catheter tip placement on insertion
	• lack of chest x-ray confirmation of catheter location
Signs, Symptoms & Data	• cardiopulmonary signs and symptoms dependent upon dysrhythmia
	• ECG irregularities
	• pulse irregularities

Interventions	• withdraw the catheter and position the tip correctly
	• artificial pacemaker for complete heart block
Prevention	• use marked spring-wire guides
	• estimate length of catheter and guide wire needed by external anatomy
	• secure catheter to prevent migration
	• chest x-ray immediately after insertion and periodically while catheter is indwelling to verify correct tip location
	• ECG monitoring during insertion
	• have pacing equipment available for catheterization of patient with existing bundle branch block

Nerve Injury

Pathophysiology	The injury of nerves occurs almost exclusively during a central venous catheter insertion into the subclavian and internal jugular sites where there are many nerve pathways in the surrounding area.[47] The damage is usually inflicted by probing during the attempt to locate the targeted vessel. The following deficits have been recorded in the literature: sensory-motor loss to the upper extremities, paralyzed diaphragm, hoarseness, Horner's syndrome and others. If the nerve was only compressed, full recovery from the nerve deficit is expected; however, if the nerve was cut or damaged in some way, the regeneration may take a long period of time or may never occur.
Occurrence/ Predisposing Factors	• subclavian or internal jugular insertion sites
	• difficult insertion
	• inexperienced inserter
Signs, Symptoms & Data	• numbness, tingling of extremities
	• respiratory difficulties
	• hoarse voice
	• painful parasthesias
	• muscular twitches
	• contraction of pupil, partial ptosis of the eyelid, enophthalmos (Horner's syndrome)
Interventions	• symptomatic
	• physical therapy

Prevention	• knowledge about complication possibility with subclavian or internal jugular catheter insertions
	• supervision of inexperienced inserters

Catheter Malposition

Incorrect placement of the catheter tip.

Pathophysiology	The tip of an indwelling central venous catheter should be located within the superior vena cava (SVC) at a level 3-4cm above the junction of the SVC and the right atrium.[35] This placement helps to prevent complications such as vessel perforation or thrombosis that can lead to cardiac tamponade, hydrothorax or catheter occlusion. Malposition of the catheter tip will predispose a patient to complications and can occur at the time of catheter insertion or spontaneously at some time while the catheter is indwelling. The probability of this occurring is dependent upon the insertion site, the individual patient's venous anatomy and the catheter material. Catheters made of "soft" materials are the most prone to malposition.
	During insertion the catheter can be advanced into the wrong vessel. Overall rates of 1-6% have been noted for all types of CVC insertion.[102] In the literature the incidence of malpositioned catheters inserted into the subclavian vein has been found to vary from 5.5 to 29%. For the antecubital approach, the incidence varies from 21-55%.[101] A study conducted by Lum and Soski that investigated malpositioned subclavian and antecubital lines revealed that the most common sites for aberrant placement were the internal jugular vein (43.4%), the axillary vein (19%), the contralateral innominate vein (11.2%) and the right atrium (9.8%).[101] Other insertion sites, such as the femoral, can be implicated with malpositioned catheters as well, but the rates are usually lower.
	Central venous catheters that have been indwelling can become malpositioned spontaneously due to a change in intrathoracic pressure, a rapid infusion or

random body movement. The change in catheter position can occur at any time after insertion and has even been reported in long-term catheters. Coughing[46,100] or vomiting[46] are two conditions that increase the intrathoracic pressure and have been the cause for a change in catheter position. Depending upon the site of insertion, random body movements can cause the catheter tip to advance beyond its intended resting point. The tips of catheters that have been inserted into the arm have been shown to advance several centimeters when the arm is abducted making it advisable to insert the catheter with the arm in that position to avoid having the catheter tip advance into the heart. Curelaru[35] noted that catheters dwelling within the internal jugular vein can advance 1.5-3cm with maximum neck flexion. This movement must be considered during catheter insertion for final tip placement.

When a catheter is malpositioned it can empty into a smaller vessel that will be adversely affected by an infusion of hyperosmolar solution or extremes of pH. Other problems that could occur in this situation include a disturbance in the blood flow pattern or partial occlusion. All of these conditions predispose the patient to thrombus formation.

Occurrence/ Predisposing Factors	• insertion site • insertion technique • patient anatomy • catheter material • significant change in thoracic pressure • rapid IV infusion • body movements
Signs, Symptoms & Data	• might be asymptomatic • inadequate blood return • pain upon infusion • leaking at insertion site • palpitations, dysrhythmias • internal jugular - gurgling sound in ipsilateral ear, hear fluids infusing, ear or neck pain[99] • abnormal central venous pressure
Interventions	• if asymptomatic, intervention might not be necessary • change patient position • attempt rapid fluid infusions • guide wire or snare manipulation • remove and replace catheter
Prevention	• insertion by experienced personnel • chest X-ray for tip location immediately after insertion and periodically while catheter is indwelling • secure catheter to prevent migration

Pneumothorax Hemothorax

Pneumothorax: A collection of air within the pleural cavity.

Hemothorax: A collection of bloody fluid within the pleural cavity.

Pathophysiology

During the insertion of a central venous catheter it is possible that the guide wire or catheter might puncture the vessel wall and enter the pleural cavity. This is especially true with a subclavian approach due to the close proximity of the subclavian vein and the parietal pleura. These two structures are adjacent at the posterior/inferior side of the subclavian vein at the point where it passes from the first rib to join the innominate vein.

A pneumothorax develops when the pleural cavity is violated and air enters. If a blood vessel, e.g. subclavian artery or vein, is lacerated in the process and blood enters the pleural cavity, a hemothorax develops. Symptoms appear due to the pressure that is exerted on the lung tissue and in more extensive cases, the heart.

The extent of a pneumo/ hemothorax can vary. Many cases can be managed conservatively;[8] however, fatal cases have been documented. Likewise, the onset of symptoms can vary from slow to rapid. Rare cases of bilateral pneumothoraces have been reported due to insertion attempts on both the right and left sides without an x-ray being taken to rule out a puncture from the initial attempts made on the first side.[103]

The incidence of pneumothorax during a subclavian catheter insertion is 0-6%[47,104] and is dependent upon the experience of the inserter. A person experienced in the procedure usually demonstrates a low rate in the range of 0-0.5%.[8]

Due to the life-threatening nature of pneumo/hemothorax it is important to consider this diagnosis when dealing with any patient who has a central line and develops respiratory distress.

Occurrence/ Predisposing Factors	• subclavian approach • inexperienced inserter • patients with COPD or bullous lung disease • positive pressure ventilation • obesity
Signs, Symptoms & Data	• onset may be sudden or gradual • pain on inspiration and expiration • dyspnea • apprehension • decreased breath sounds over affected side • decreased chest wall movement • tachycardia • advanced:hypoxia, shock • diagnostic chest x-ray
Interventions	• O_2 administration • chest tube, needle or catheter drainage • if respiratory distress during insertion, stop and assess for hemothorax/pneumothorax • hemothorax: fluid replacement, blood transfusion, as needed • treatment according to extent of pneumo/hemothorax
Prevention	• supervise inexperienced personnel • do not use subclavian approach on high risk patients, e.g. COPD, positive pressure ventilation • chest x-ray after each procedure whether or not successful • verify non-visualized catheter tip location by dye insertion

Delayed Complications

Catheter-Related Infection	The state or condition in which, due to an indwelling catheter, the body or a part of it is invaded by a pathogenic agent that, given favorable conditions, multiplies and produces injurious effects.
Pathophysiology	Indwelling intravenous catheters are prone to infection. The catheters bypass the cutaneous protective barriers and provide a direct route of entry for microorganisms. In addition, the catheters are foreign bodies within the host and serve to alter the local immune response.[109] Within minutes of a catheter insertion a film of proteinaceous material and blood components begins to form on its surface. This film encases the intravascular portion of the catheter within a fibrin sheath. With further progression a thrombus may form. If bacteria are introduced into the area the fibrin sheath and thrombus serve as a bed for bacterial adherence and growth.[122] Some bacteria, such as certain strains of coagulase negative staphylococci, produce a glycocalyx or "slime" which serves as further protection for the microorganisms.[111] Once the organisms have taken up residence on the catheter there are a number of conditions that may follow, either localized or systemic. The best way to determine whether the catheter is the infection culprit is to perform quantitative or semiquantitative catheter cultures along with peripheral blood cultures. The most popular method is the semiquantitative method developed by Maki[116] in which portions of the catheter are removed aseptically and rolled on blood agar plates. If the culture grows <15 colonies the catheter is probably contaminated, but growth of 15 colonies has been associated with local infection or systemic infection if peripheral blood cultures match the plated organism(s). Purulent drainage from the catheter site is also a positive indicator of localized infection.

Using a semiquantitative method for catheter culture the following definitions are applicable to the diagnosis of infection:

<u>sterile</u> - no growth

<u>contamination</u> - <15 CFU (colony-forming units) from catheter tip or intracutaneous catheter segment.

localized:

<u>colonization</u> - organisms present without symptoms: 15 CFU from catheter tip and/or intracutaneous catheter segment; present in 5-25% catheters removed.

<u>insertion site/track infection</u> - 15CFU on culture from catheter tip and/or intracutaneous catheter segment; may have external signs and symptoms of localized infection.

<u>tunnel infection</u> - 15 CFU on culture from catheter tip and/or segment from tunneled portion of catheter; external signs and symptoms along tunnel track.

systemic:

<u>catheter-related or primary catheter bacteremia</u> - 15 CFU on culture from catheter tip and/or intracutaneous catheter segment and positive peripheral blood cultures with the same organism; no other site of infection identified.

Other conditions that can be associated with indwelling IV catheters are suppurative thrombophlebitis, in which a thrombus that has developed at the catheter site becomes infected, and systemic extension of the catheter-related infection to other sites, e.g. endocarditis.

There are three mechanisms by which indwelling IV catheters can become colonized/infected with microorganisms.[106,112,113] The most prevalent cause is the migration of organisms down the external surface of the catheter via the intracutaneous track to the fibrin sheath. Usually the organisms are from the patient's skin flora. The catheter can also be contaminated during handling, and the causative organisms will be from the hands of the person manipulating the catheter, contaminated antiseptic solution, or some other external source. Another mechanism for the introduction of organisms into the catheter is the infusion of contaminated IV fluid. The contamination can be attributed to the organisms growing within the fluid or to the introduction of organisms into the internal lumen of the tubing or catheter through in-line sites such as stopcocks, transducers, and hubs. This type of contamination is usually related to the amount of manipulation to which the line is subjected. The third way that IV catheters become colonized is by seeding from a remote infection site during transient or continuous bacteremia.

The organisms that cause most catheter-related infections are found on the skin, most notably coagulase negative staphylococci.[118,126] *Staphylococcus aureus*, *Candida*, and some gram-negative bacilli have also been implicated, but to a lesser degree.

Occurrence/ Predisposing Factors	• difficult insertion or inserter lack of experience • break in aseptic technique • established remote infection • prolonged placement • increased frequency of catheter manipulation • type of device • use of TPN • patient status (e.g. age, immune compromise, etc.) • stiff or "rough" catheter material • inadequate site care • contaminated equipment or infusate
Signs, Symptoms & Data	**local:** • erythema, tenderness, induration, may be purulent exudate, fever • positive exudate culture and/or Gram stain **systemic:** • fever without another source, chills, hyperventilation, nausea, vomiting, malaise, headache • may progress to shock with certain organisms (hypotension, increased heart rate, nausea, vomiting, confusion, seizures, death) • positive peripheral blood cultures

	• positive semiquantitative or quantitative cultures of the tip of the catheter and the intracutaneous segment
Interventions	• determined on a case-by-case basis
	• in questionable cases the catheter may be changed over a guide wire and the tip and intracutaneous segment cultured - if the catheter cultures are negative the newly placed catheter remains - if the catheter cultures are positive the catheter is removed and a new catheter is inserted into another site.[121]
	• may remove catheter
	• may remove catheter and treat with anti-biotics specific to the pathogen(s) involved
	• may keep catheter in place and treat with antibiotics specific to the pathogen(s) involved
Prevention	**known:**
	• meticulous aseptic technique
	• hand washing prior to insertion or any manipulation
	• experienced and knowledgeable personnel to insert
	• remove the catheter as soon as it is no longer needed
	• maintenance by IV team or highly educated personnel
	• occlusive dressings
	• routine site care according to established hospital protocol
	• routine replacement of IV setup and infusate
	• antimicrobial subcutaneous cuff[114]
	• antiseptic bonded catheters[117]
	• mix solutions under laminar flow hood
	• observe infusate containers for cracks or cloudiness
	• anchor catheter securely
	• maximal sterile barrier precautions (sterile gloves, drape, mask, gown, cap)[272]
	controversial:
	(see Catheter Maintenance section)
	• type of dressing (gauze vs. transparent)
	• frequency of dressing change
	• use of antibiotic ointment

• type of antibiotic ointment (PNB, iodophor, mupirocin)
• antiseptic for skin cleansing (iodophor vs. chlorhexidine)
• routine catheter change over guide wire

Catheter-related Thrombosis	The formation, development or existence of a blood clot or thrombus related to the presence of an intravenous catheter within the vascular system.
Pathophysiology	Catheter-related thrombosis is a common occurrence during central venous catheter use. Although usually not significant, in a certain percentage of cases progression of the clot or fibrin sheath formation can cause catheter malfunction or serious patient problems. The incidence of thrombosis has been shown to range from 0.3-71%.[53] Symptomatic cases are usually found in less than 5% of the catheters entered into documented studies.[133]

The form of thrombosis that is found most frequently is the fibrin sheath that develops around the catheter body while it is indwelling. The process begins as soon as the catheter is inserted and is precipitated by the body's reaction to the catheter as a foreign object. In the blood stream, platelets and fibrin are deposited along the catheter body. The speed at which this occurs is related to the smoothness of the catheter surface.[35,131,132] As the process continues, a "film" is formed that can encase the entire intravenous portion of the catheter. When the lumen openings become involved a partial occlusion can result that mimics the action of a ball valve, i.e., fluids can be infused but not withdrawn.

Another type of thrombus involves the vessel wall and can form at the site where the catheter enters the blood vessel or where the tip rubs against the vessel wall. The process is initiated by the injury to the lining of the vessel. Platelets gather and clump at the site and the clot continues to grow.

This type of clot is called a mural thrombus. If the growth continues unchecked, it may result in occlusion of the blood vessel. One of the worst complications that can result from central venous occlusion is superior vena cava syndrome in which the superior vena cava is blocked. This condition can lead to fatal cerebral and vocal cord edema. Fortunately, it is an uncommon occurrence.

A correlation has been made between the formation of a fibrin sheath or a thrombus and adherence of microorganisms to the resultant rough surface. If the thrombus becomes infected, a septic condition can develop that usually requires removal of the affected portion of the vein for resolution.

Thrombi must also be viewed as a possible source for emboli that can migrate to other locations, most frequently, the lungs.

Occurrence/ Predisposing Factors	• duration of indwelling catheterization • rigidity of catheter material • hypertonic or irritating solutions • coagulopathies • sluggish flow through vessels • repeated use of a vein
Signs, Symptoms & Data	• rare signs and symptoms • may be subtle and delayed • poor catheter function • withdrawal or partial occlusion • insertion site edema • occlusive: prominent superficial collateral veins, neck pain, numbness or tingling in ipsilateral extremity, change in skin temperature or color, swelling in ipsilateral arm, neck or face • pain along vein • fever, malaise • tachycardia
Interventions	• diagnostic study, i.e. venography, ultrasonography • remove catheter, if indicated • anticoagulant therapy • thrombolytic therapy • warm compresses to affected area
Prevention	• avoid using "stiff" catheters • remove catheters when no longer needed • secure catheters

• dilute irritating solutions
• use least thrombogenic catheters
• maintain IV flow
• maintain optimum patient hydration
• utilize routine flushing procedures

Hydrothorax

Vessel erosion	A non-inflammatory collection of fluid in the pleural cavity.
Pathophysiology	Although a hydrothorax can develop soon after a catheter is inserted due to vessel perforation, it is more often the result of the catheter eroding through the vessel wall. The erosion is usually caused by the friction created when the catheter tip rubs or presses against a point on the wall. The process can be compounded by chemical irritation of the vessel intima due to the infusion of hyperosmolar solutions. Over a period of time, the vessel wall is damaged to the extent that the vessel is perforated and the solution infuses into the thorax, mediastinum or gut, depending on the catheter insertion site. With increasing fluid collection, pressure is exerted on vital organs with resultant signs and symptoms. The incidence at which vessel erosion occurs is 0.4-1.0%.[134]
Occurrence/ Predisposing Factors	• catheter tip against vessel wall • left-sided approach • hyperosmolar infusion • stiff catheters
Signs, Symptoms & Data	• fast or slow onset • failure to aspirate blood • increasing hypoxia • chest pain • cardio-respiratory compromise • mediastinal widening
Interventions	• discontinue fluid administration • oxygen administration • diagnostic chest x-ray • remove catheter and evacuate fluid • thoracentesis or mediastinal fluid aspiration

Prevention
- awareness of potential development
- use catheter of soft material with pliable tip
- right-sided approach when possible
- catheter of sufficient length for left-sided approach to achieve proper catheter placement so tip is parallel to vessel wall
- chest x-ray after insertion and periodically to check catheter tip placement

catheter *maintenance*

Central venous catheters are invasive devices that predispose the patient to complications that are costly in financial terms as well as in patient morbidity and mortality. Methods used in the care and maintenance of the catheter during insertion and while indwelling can have a significant effect upon the incidence of catheter-related complications. It is vital that health care personnel be knowledgeable and experienced in the care of central venous catheters, and that policies, procedures and protocols be based upon available scientific studies that support the methods chosen for that care.

Due to a lack of study or conflicting available study results, there are **ongoing debates about the best methods for use in some aspects of catheter care.** For these issues, consideration should be given to conducting research in an effort to develop the scientific basis for standards of care.

Dressings

The placement of a dressing over the catheter insertion site serves a number of purposes. It must be occlusive and water-repellent to protect the area from extrinsic contamination and to keep the site clean of any secretions or drainage from surrounding anatomical sites. The dressing also helps to stabilize the catheter and aids in the protection of the catheter body close to the insertion site. Sterile supplies must be used to prevent the introduction of pathogenic microorganisms at the time the dressing is applied.

An ideal dressing would consist of materials with the following attributes: is safe and comfortable for the patient, is easy to apply and remove, provides an occlusive seal and clear observation of the site, is waterproof and provides protection against infections. In addition, the dressing should be inexpensive and readily accessible. Unfortunately, the ideal dressing has not yet been developed. Practitioners must attempt to provide optimal protection by manipulating the elements involved in the maintenance of the catheter dressing. The elements include (1)the type of dressing material; (2)skin preparation; (3)redressing interval; (4)aseptic technique; (5)use of antimicrobial ointment; (6)hand washing and; (7)health care worker expertise.
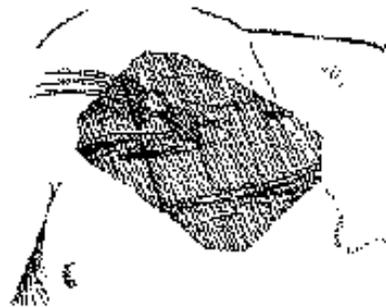
Of the elements, those with the highest level of acceptance within the medical community are the use of aseptic technique, hand washing and the skill of the person redressing the site. The other elements are surrounded by controversy and need to be discussed individually.

Dressing Material

The classic IV dressing has consisted of gauze secured with tape; however, the introduction of transparent, semipermeable dressings has initiated a controversy as to which dressing material is superior. Each has its advantages and disadvantages.

	Advantages	Disadvantages
gauze & tape	• low cost • adherence	• frequent changes for visual site assessment • contaminated by secretions/discharge/moisture • patient discomfort, irritation and bulk

	Advantages	Disadvantages
transparent	• continuous visual assessment • patient comfort • longer dressing change interval • less maintenance	• increased microbial colonization of the site • lack of adherence to diaphoretic skin • skill to apply • increased cost per unit

Transparent, semi-permeable dressings became popular due to the decreased amount of maintenance that is needed to care for such dressings and the ability to continually observe the site. A number of studies have supported the use of these dressings although the study protocols varied.[115,139,142-144,145,147]

A concern that has repeatedly appeared in the literature has been the increase in colonization,[138] and in some institutions the infection rate,[137,140,142,146] with the use of the transparent membranes. The problem seems to stem from the build up of moisture under the dressing. Aly and associates[136] studied the effect of prolonged occlusion on the skin and found that the number of microorganisms increased significantly during the first five days an occlusive dressing was in place. A corresponding increase in water under the dressing was demonstrated. Since skin organisms are considered the main source for catheter colonization and infection, such growth could serve to explain the infection and colonization rates found in the studies of transparent dressings.[137,138,140,142,146] In response to the problems with moisture buildup, new products are being developed that allow for increased release of water.[144]

Despite conflicting findings, transparent dressings continue to be widely used as hospital personnel continue to weigh the advantages and disadvantages of dressing materials.

Skin Preparation

Each time the insertion site is redressed, the area surrounding the catheter entrance point should be treated with an antiseptic solution. The purpose of using an antiseptic is to reduce the number of skin organisms at the insertion site. The choice of agent is debatable. The main antiseptics that are used are alcohol, tincture of iodine and povidone-iodine. Chlorhexidine has more recently been shown to also be an effective agent and, unlike the others, exhibits a residual antimicrobial effect after drying. (See Site Preparation Section for more information.)

Defatting the Skin

The purpose of defatting the skin is to reduce microbial skin colonization. The agents used most frequently are alcohol, acetone and ether; however, defatting using acetone and ether often causes pain and inflammation at the catheter site. Recently, the practice has come under scrutiny due to patient discomfort and the loss of the proposed antimicrobial effects of the free fatty acids on the skin.[149] One study by Maki[148] found no significant antimicrobial benefit to defatting and opens the way for further investigation. The practice is still widely used but should be evaluated by practitioners to weigh the benefits versus patient discomfort.

PRECAUTION: Acetone, alcohol and ether have been shown to weaken polyurethane and silicone materials. If the skin around the insertion site is defatted using any of these agents, care must be taken not to allow the solution to come in contact with the catheter body or pigtails.

Skin Preparation Guidelines

- cleanse the area around the catheter including under the hub
- cleansing should be performed using a circular motion moving in concentric circles from the site outward
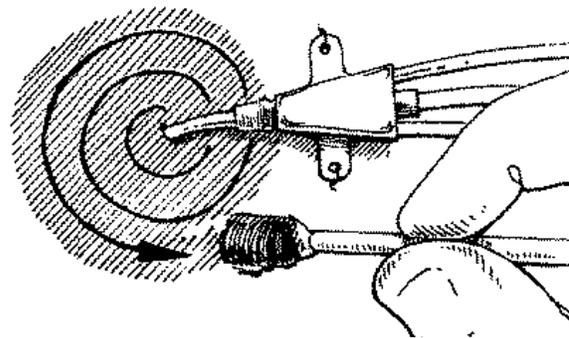
- prepare an area the size of the final dressing
- use the antiseptic of choice properly to achieve the maximum benefits, e.g. alcohol must be applied vigorously for two minutes and povidone-iodine must be allowed to air dry completely.

Antimicrobial Ointment

Another area of controversy is whether an antimicrobial ointment should be used under the dressing at the insertion site, and if the answer is yes, which one?

The use of an antimicrobial ointment is designed to further guard against the development of catheter-related infections; however, there has been a lack of conclusive research to show the benefit of ointment use, and existing studies are difficult to compare due to differences of protocol. Some success has been attained with polymixin - neosporin - bacitracin (PNB) ointment in reducing colonization or infection caused by gram- positive microorganisms; however, PNB ointments are not effective against gram-negative organisms or fungi which are pathogens associated with central venous catheter use.[151,152] In response, the recommendation has been made that if antimicrobial ointments are used, povidone-iodine products are best for central lines due to the broader spectrum of organisms against which they are active. More recently a study has been performed using mupirocin, a topical antibacterial that is active against gram-positive organisms. Candida was not a problem in this study,[150] but more research is needed. In general, the results of the studies to date have caused some researchers to describe the benefit of any antimicrobial ointment as "modest".

In addition to the questionable efficacy of using an antimicrobial ointment, other problems must be considered. If used with a transparent membrane dressing, an ointment covers the insertion site and negates the advantage of site visibility. The amount of ointment that is used is also important, since too much may interfere with the membrane adherence. A question can also be asked about how long the ointment will be effective given the longer periods of time between redressing that are part of some hospitals' protocols. One opinion held by some practitioners is that the ointment provides a wetter environment under the occlusive dressing that may lead to organism growth resistant to the antimicrobial.

The **final decision for or against an antimicrobial ointment should be based upon a review of the literatur** e, consideration for other dressing attributes that may be affected and the documented rate of infection within the hospital setting. Consideration of the added costs might weigh heavily against a treatment that has not been proven beneficial.

Redressing Interval

Hospital protocols vary with respect to the amount of time a central venous catheter dressing is left in place. The situations for redressing that are universally accepted are when a dressing is no longer adherent or occlusive and when a gauze dressing becomes soiled. Routine redressing protocols vary concerning the interval between changes from daily up to the lifetime of the catheter or dressing, whichever comes first. Some protocols provide for a redressing when the IV tubing is changed at 48 to 72 hours depending on the hospital policy. Longer intervals are often used in correlation with the use of transparent dressings,[3,115] and in fewer cases have been extended to gauze redressings.[115]

Due to the lack of data, the choice must be made within individual hospitals based on patient factors, infection rates and the type of dressing desired.

Redressing Procedure Guidelines

• hands must be washed thoroughly prior to the redressing

• Universal Precautions must be observed

• to prevent cutting the catheter when removing old dressings, do not use scissors or sharp instruments

• use strict aseptic technique, sterile gloves, masks (gowns when required)

• if possible, turn patient's head away from dressing site or have patient wear a mask

• visually examine insertion site at least daily or with each dressing change for erythema, drainage, tenderness, suture integrity and catheter position

• use circular motion to cleanse the area around the catheter, working from the site out in concentric circles and under the catheter hub

• document dressing change with the date and initials of person redressing

Delivery System

In an effort to keep the number of microorganisms within the IV set-up at a minimum, the solution and tubing should be changed at regular intervals. Although most catheter-related infections are caused by skin organisms migrating down the subcutaneous catheter track, it is possible to have an infection develop due to contamination of the infusate. If the IV set or solution hangs for prolonged periods of time, there is more risk of introducing a significant number of organisms as a result of frequent manipulations. Concerning the solution, if small numbers of certain Gram-negative rods, e.g. *Klebsiella* species, *Enterobacter* species are present in certain solutions as contaminants, a prolonged hanging time would allow the organisms to multiply to significant numbers.[113] In both cases the result could be a catheter-related bacteremia.

In the 1970's, in response to epidemics of IV-related infections caused by intrinsically contaminated IV fluids, the Centers for Disease Control and Prevention (CDC) made the recommendation to change IV administration sets every 24 hours. Studies in the late 1970's and early 1980's demonstrated that it was possible to extend the interval to every 48 hours with the exception of TPN which was not included in all of the studies.[153-155] This information was included in the CDC Guidelines for the Prevention and Control of Nosocomial Infections.[158] In 1987 research was published that demonstrated it was possible to extend the interval for IV tubing

change, including TPN to at least 72 hours.[156,157,159] The following infusion sets were exempted from the 72 hour change: blood, lipids, arterial pressure monitoring and all infusions during an IV-related epidemic. These IV sets should be changed more frequently, i.e., after each infusion (blood administration) or every 24 to 48 hours.[113]
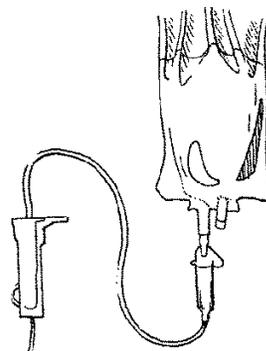
Since microorganisms can proliferate within solutions, the amount of time that it takes for a bag of solution to infuse is important. The frequency with which the bags must be changed is determined by the capacity for bacterial growth and/or the breakdown of components within the solution. For example, bags of IV fluids that are used at a slow rate to keep the line patent should be changed every 24 hours according to CDC.[158] Protocols in some

hospitals have been changed to correspond with tubing changes at 48 to 72 hours as long as the system remains closed. Blood should not infuse for longer than 4 hours.[113] Hyperalimentation should not hang for more than 24 hours, and infusions of lipid emulsions have a 12 hour limit.[158]

Slide Clamps

Slide clamps are provided on each pigtail to facilitate tubing or injection cap changes. The clamps should not be considered a guarantee against air entry while the catheter is indwelling due to the shape and ability of the clamp to "slide" off given the right circumstances, e.g. patient movement or tampering. Instead, emphasis must be placed on the use of tightened luer lock connections as a vital step in the prevention of an air embolus.
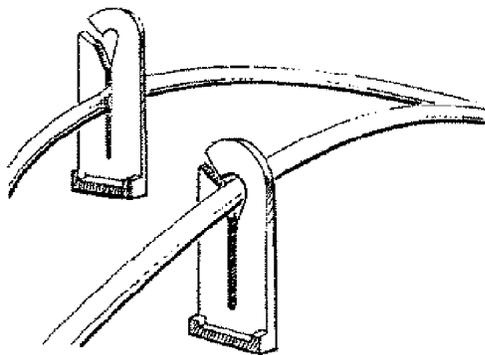
Tests have been performed to determine the effect of Arrow clamp placement on the catheter pigtails.[160] During one trial the clamp was maintained in a closed position for a prolonged period of time (1 week). When released the flow rates were temporarily reduced for approximately one hour before returning to pre-test levels. The clamp can also be applied repeatedly; however, an attempt should be made to vary the clamp position along the pigtail.

The slide clamps are removable. In situations where the slide clamps may be inadvertently removed and potentially aspirated by children or confused adults, they can be taken off and reapplied only when needed. Do not substitute other clamping devices, such as hemostats, for the slide clamps. Serrated and sharp edges may damage the pigtails.

Primary Injection Sites

When continuous infusions are no longer needed, the pigtail hub is occluded by using a Luer-Lock injection cap. The caps are utilized as sites for intermittent infusions or injections. Because the caps are handled repeatedly, it is possible that pathogenic microorganisms can enter at the hub during a manipulation. To reduce the chance of the caps becoming a source of catheter-related infection, it has been recommended that they be changed at regular intervals. Many protocols provide for the caps to be changed every 72 hours in conjunction with tubing changes. A
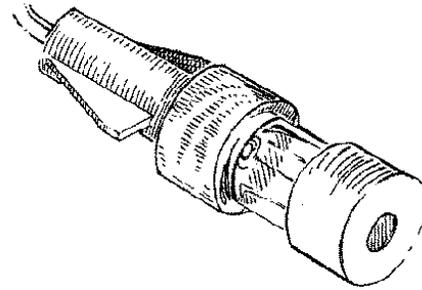
factor that helps to determine how often the caps are changed is the number of manipulations to which they are subjected. In some situations the interval between changes has been extended in hospital/agency protocols such as with a long term catheter through which treatments are given infrequently.

Every manipulation must be performed using aseptic technique, and prior to each puncture the injection site must be wiped with an effective antiseptic, e.g. alcohol or iodine. Likewise, before each cap change, the hub should be cleaned with an antiseptic solution prior to disconnection.

The injection caps can withstand repeated punctures. The Arrow cap (UG-14703) has been tested with a 22 Ga. dry needle and a needle free hub each used 50 times. The hub did not leak after the test completion.[161]

Maintaining Patency

When a catheter lumen is no longer used for continuous infusions, it can be capped and "locked" in preparation for intermittent or future use. To "lock" a catheter lumen a solution must be instilled to fill the entire space of the lumen and injection cap. Theoretically this prevents a backflow of blood that would cause clotting within the catheter. Some procedures call for using larger amounts of solution to "flush" the catheter. A controversy exists concerning which solution is most appropriate, a heparinized saline solution or saline alone.

Heparinized saline has been used primarily due to the antithrombolytic properties of heparin. Heparin inhibits clot formation by inactivating thrombin and other coagulation factors.[192] There are few adverse effects routinely attributed to heparin. Hemorrhage (7-10%) and allergic reactions (2-5%) are the most prevalent, but in the past decade another complication of heparin administration, heparin-induced thrombocytopenia and thrombosis syndrome (HITTS), has received much attention.[166,168,183-185] HITTS is associated most frequently with continuous IV heparin therapy, but it has also occurred with intermittent subcutaneous and flushing/locking administration[171,181,188,191] and in one report was associated with heparin-coated pulmonary artery catheters.[186] HITTS occurs in approximately 5%-30% of persons receiving heparin.[166,187,191,196]

Two clinical presentations of heparin-induced thrombocytopenia and thrombosis syndrome have been identified. One is a mild form characterized by a transient decrease in platelets that usually occurs around the second or third day of therapy. This is the most frequent presentation. The other type is believed to be an immune response to heparin and occurs 6 to 12 days after therapy is started.[185] It is characterized by a severe decrease in platelets that may be accompanied by thrombosis, the result of platelet aggregation. The clots may form in arteries or veins and affect any portion of the body including organs. The clotting phase of the disease has also been called "white clot syndrome" due to the color of the clots which consist of platelets and fibrin. Although this presentation is rare (0.6%), the incidence of limb amputation has been reported as 21% and the mortality rate 29%.[166]

Consideration of the serious side effects of heparin, cost containment and the systemic antithrombolytic effects that can occur with heparin flush/lock have led researchers to investigate other regimens for maintaining catheter patency. Most research has been conducted using peripheral indwelling intermittent infusion devices (heparin locks); however, studies can be found that used arterial lines, peripherally inserted central catheters (PICC) and central venous catheters. **Generally, the information from these devices has been applied to the maintenance of multiple lumen catheters.**

The current literature identifies the most widely used concentration of heparin used in intermittent peripheral devices as 100 U/ml 0.9% sodium chloride solution.[163,169,170,174] Studies have also demonstrated success with 10 U/ml[164,180] and saline alone[165,167,172,173,175,176,178,179,190,194,195] and have measured success by the number of IV restarts that are needed due to clotting or patient complications such as phlebitis. Meta-analyses of similar research projects have served to support the use of saline in indwelling intermittent devices.[177,189] Advantages that have been attributed to saline use are as follows: decreased exposure of the patient to the effects of heparin, decreased risk of medication errors, decreased nursing time, cost effectiveness, avoidance of drug incompatibilities, and avoidance of heparin hypersensitivity reactions.

Various concentrations of heparin, 0-1000U/ml. normal saline have successfully been used in Arrow central venous catheters. The concentration needed to maintain patency is a clinical issue and must be based on factors specific to the patient population and treatment setting.

Another aspect of the procedure that is not standardized is the frequency with which the IV device is flushed. A regimen used frequently is to flush at the time of medication administration using the S.A.S.H. method and at least every eight hours or once per shift. The S.A.S.H. method consists of a flush of saline, followed by the medication, another saline flush and finally, heparin to lock the

device. This prevents the interaction of heparin with other medications. Without heparin an S.A.S. routine is used. The range of intervals in published surveys of flushing protocols is mainly every eight hours to 24 hours in hospital settings and extends to longer periods in the home setting.[174]

The volume of solution to use is another factor that must be considered. The range of volumes used extends from the exact volume of the lumen to 6 ml in one study when saline alone was instilled every 24 hours.[190] The volume is more critical if a heparinized solution is used. If too much is given, the patient's coagulation status may be altered. For peripheral devices the Revised IV Nursing Standards of Practice recommend the use of a minimal concentration of heparinized saline of an amount that is 2x the size of the lumen.[182] There is no standard for central venous catheters.

Considering the elements involved in the flushing/ locking of IV devices, solution <u>concentration</u>, flush <u>frequency</u> and <u>volume</u>, there are many combinations that can be used.[163,170,174] The trend seems to be moving toward the use of the least of each of the elements that will be successful given the patient condition and circumstances. That is, use the least amount of heparin (down to 0) in the smallest volume using the longest interval between doses that still keeps the lumen patent. Currently, this approach seems applicable to most intravenous devices.

In contrast, the recently published results of the Thunder Project, a research project conducted through the American Association of Critical Care Nurses, found that heparinized saline solution was definitely preferable to maintain the patency of arterial lines in certain patient populations.[162] The large sample of patients (n=5139) gave credence to the study that was conducted in 198 U.S. hospitals. Other factors, in addition to heparin, that were associated with arterial line patency were: additional anticoagulant or thrombolytic therapy, catheters longer than 2 inches, femoral insertion and male gender. Using these factors can help to determine the population for which heparinized saline should definitely be used. Determination of the need should be made on a patient-to-patient basis.

Flushing/Locking Guidelines

- use aseptic technique
- cleanse injection hub with approved antiseptic solution
- monitor patient clotting factors during heparin use
- use a 10 cc or greater syringe for flushing/locking to reduce the risk of exceeding pressure capacity of the catheter[92]
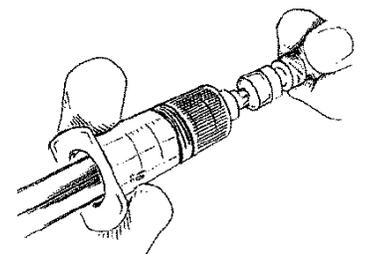
- maintain gentle positive pressure on syringe plunger while removing from injection hub
- observe Universal Precautions

Blood Sampling

While a catheter is indwelling, it is usually necessary for the patient to have blood samples withdrawn for laboratory testing. The ideal site for blood sampling is a peripheral vessel; however, a central venous catheter is often inserted into patients who have no available peripheral sites making blood withdrawals through the catheter a necessity. Due to the patient's condition, it may also be beneficial to use the catheter for blood sampling to avoid added stress or sleep disruption.

When a multiple lumen catheter is used for sampling the proximal port is usually chosen for the procedure. The rationale for the choice is that if solutions are infusing through the other ports of the catheter, they will be carried away from the sampling port by the flow of blood within the vessel, thus reducing the chance for contamination of the specimen.[198] For additional insurance that the laboratory results will not be altered, the distal infusions should be turned off for at least one minute before the blood sample is obtained.

Syringes or a vacuum setup can be used to withdraw the blood from the catheter. If syringes are used, it is important to aspirate slowly to prevent hemolysis of the specimen and/or collapse of the catheter or vessel. Bubbles in the blood as it is being aspirated signal that too much force is being applied. After the blood is withdrawn, the syringe is used to transfer the blood into the appropriate laboratory test tubes. A vacuum setup is appropriate for use with pigtails or sampling ports that are secured with a Luer-Lock injection cap and provide for flow of the blood into the designated evacuated test tubes.

Several methods can be used to withdraw a blood specimen through a central venous catheter. Withdrawal can be performed 1) through an injection port, 2) by opening the system or 3) through one or two stopcocks depending upon whether the initial amount of solution aspirated is to be reinfused. All sampling attempts represent an opportunity for microbial contamination of the systems so use of strict aseptic technique and meticulous hand washing are of the utmost importance.

Of the three methods, the open technique is the most risky in terms of microbial contamination. This technique requires the removal of the injection cap or disruption of an infusion to facilitate the attachment of various syringes to the Luer-Lock connection of the catheter. The exposed hub is a well-documented source of catheter-related infection, and the amount of manipulation required during the procedure is a contributing factor to catheter colonization that can lead to infection. The use of stopcocks can be dangerous for the same reason: the amount of manipulation needed for the procedure predisposes the system to microbial contamination, up to 46% in a study by Dryden.[204]

The actual steps taken in the blood sampling procedure depend on a number of variables, e.g. whether the line is used for an infusion (including TPN), whether the catheter is locked with heparin vs. normal saline, whether the catheter is heparin-coated, and the condition of the patient. If there are compounds within or on the surface of the catheter that would alter the study results, attempts must be made to remove them. Examples are electrolyte-or glucose-containing solutions if the patient's electrolytes or blood sugar are to be measured, or the presence of heparin if coagulation studies or potassium levels are ordered.[202,209] To clear the offending solution, a discard sample must be withdrawn. Some hospital procedures provide for an initial saline flush as further assurance that the line is cleared. A word of caution about flushing is necessary if the catheter is filled with a concentrated heparin-lock solution such as 100 U/ml of saline solution because if blood samples are taken frequently the flushing may provide the patient with a therapeutic dose of heparin that could be detrimental.

The amount of blood that is needed for discard is a controversial topic and many studies have been performed to determine the amount of discard that is necessary to assure accuracy of the test result. Most of the research has been conducted using arterial catheters that are flushed with a dilute heparin solution to maintain patency. Very little information is available for multiple lumen catheters that may utilize more concentrated heparin solutions. The studies that have been conducted using arterial catheters are very difficult to compare due to differing study designs and a lack of priming volume information for interpretation of results.[215]

Recommendations for the discard volume in arterial and central venous catheters have ranged from the priming volume (dead space) to moderate amounts (3-6ml)[201,203,207,210,212] to 10ml[208,216] with the largest volumes being used for heparin-locked or flushed catheters when drawing coagulation studies. Another way the recommendation has been stated is in the number of priming volumes that are necessary for clearing the lumen, a range of 2x to 6x its volume.[211,213] A few references continue to resolutely state that coagulation studies should not be drawn from heparinized lines.[197,216]

The practice of taking blood cultures through a catheter is discouraged due to the rate of catheter lumen colonization.[199] Blood cultures through a line would only be applicable in an attempt to diagnose a catheter-related bacteremia as previously discussed in the "Complications" Section.

A concern that is frequently expressed is the amount of blood that a patient, especially in a critical care setting, loses to laboratory testing when the sample and discard volumes are combined. Smoller and Kruskall[214] looked at total amounts of blood drawn from patients on general wards and in the intensive care unit. The results of their record review revealed that the patients on general wards had blood drawn on an average of 1.1 times each day for a mean daily volume of 12.4 ml and a total amount of 175 ml for their entire hospital stay. In contrast, intensive care patients had blood drawn on an average of 3.4 times per day at a mean daily volume of 41.5 ml and a total volume of 762.2 ml. If the patients had arterial lines, the total increased to 944.0ml. Similar results were shown in research by Eyster[205] and Foulke.[206] Some patients require transfusions to treat the iatrogenic anemia that results from such frequent blood sampling.

In response to the concern about iatrogenic anemia from blood sampling, many procedures have been changed to provide for the lowest discard and sampling volumes and least frequent testing schedules that are possible considering the patient's condition and IV or arterial line regimen. Strategies that have proven useful to accomplish this goal include the use of smaller test tubes in accordance with laboratory instrumentation, batching of laboratory samples, documentation of patient blood loss on the chart or flow sheet, in line infusion set-ups that provide reservoirs and allow for immediate reinfusion of the discard specimen, and new technologies that allow for laboratory testing at the bedside using minimal amounts of blood.[200,214]

Final decisions about blood sampling should be made in conjunction with the laboratory and take into consideration the solutions that are being infused, the presence or absence of heparin within the catheter, the lumen priming volume, the frequency of sampling, and the patient's welfare. More research is needed in this area.

Blood Sampling Guidelines

- use aseptic technique and meticulous hand washing

- use peripheral sites whenever possible

- cleanse hubs, injection ports and stopcocks with an approved antiseptic

- avoid opening the system, whenever possible

- utilize strategies to minimize patient blood loss

- reduce manipulation of the system, whenever possible

- review laboratory results carefully to detect error related to blood sampling techniques

- replace injection caps that become contaminated with blood

- turn off infusions for one minute prior to sampling, if possible

- do not apply too much pressure when aspirating through a catheter using a syringe

- use the least amount of discard blood that is possible to achieve an accurate laboratory test result

Home Care

In today's health care environment, patients are living at home with central venous catheters in place. The basic principles for care and maintenance of the catheters apply to all settings but must be tailored to meet the specific patient's needs and conditions found within the home.
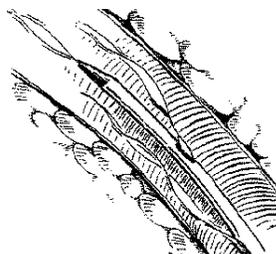
Infusions

A major advantage to using multiple lumen central venous catheters is the ability to deliver multiple infusions through one percutaneous IV site. Due to tip placement within a large central vein the scope of treatment is expanded to include solutions that could not be given peripherally. Proper tip placement in a large vessel is of utmost importance to ensure rapid dilution when such fluids are infused. If a hypertonic solution is infused into a smaller vessel, the risk of thrombophlebitis or vessel erosion is increased significantly.

Solutions that are infused through multiple lumen catheters may include routine replacement fluids, e.g. 0.9% sodium chloride or 5% dextrose in water, medications, blood products and hyperalimentation. Consideration must be given to the effects that certain medications may have upon the catheter as well as other simultaneous infusions. Examples are: the leaching of plasticizers from polyvinyl chloride (PVC) material, the weakening of polyurethane by alcohol, the absorption or adsorption of medications to certain plastics such as PVC, and medication incompatibilities.

Incompatible Infusions

Certain medications/solutions will interact when they are in direct contact. The results may be the formation of a precipitate, a change in drug potency, total inactivation of a medication or the

formation of toxic or harmful products.[219,222] The simultaneous infusion of incompatible medications through a multiple lumen catheter has raised concerns about these possible results.

The infusion of incompatible medications is possible through a multiple lumen catheter,[220] but studies have shown that important factors for success are a sufficient blood volume and the configuration of the lumen exits at the distal portion of the catheter body.[217,218,221] The blood volume is determined by catheter tip placement, patient hydration status and cardiac output. Concerning the exit holes, when they are staggered and rotated around the circumference and along the length of the catheter, there is much less chance for interaction between incompatible medications because the proximal infusions are diluted within the blood flow by the time the next exit hole is approached. Central venous catheters that are constructed with the exit holes side-by-side have demonstrated more precipitate formation.[218]

Infusion Guidelines

- infusions should be monitored frequently to ensure proper flow rate and medication delivery

- the catheter should be flushed after medication administration to deliver any residual portion of the dosage to the patient and to prevent interaction of the medication/solution with future infusions

- due to the potential for infection, one lumen should be designated for TPN use only

- medications containing high concentrations of alcohol should not be infused through polyurethane catheters

- medications/solutions such at Taxol or lipid infusions should not be infused through catheters made of polymers that contain plasticizers, e.g. PVC, **(polyurethane does not contain plasticizers)**

- consideration must be given to dosages of medications, e.g. nitroglycerin or insulin, that are absorbed or adsorbed by certain polymers, e.g. PVC.

monitoring

Multiple lumen central venous catheters can be used to monitor cardiac function. The location of the catheter lumen exit holes within the superior vena cava (SVC) make it possible to measure the central venous pressure (CVP), a reflection of the pressure in the right atrium. The CVP provides valuable information about the efficiency with which venous blood is returned to the heart, the intravascular blood volume and right ventricular function. The normal range for CVP values is 0-7mm Hg with 3mm Hg considered as a normal average.[27] A low CVP is an indication of fluid depletion, and an elevation signals right ventricular failure. Measurements can be made using a manometer or calibrated pressure transducer system.

The distal lumen of a multiple lumen catheter has usually been employed for CVP measurement. The rationale for this choice is that the distal lumen is larger and the lumen exit is closest to the right atrium; however, theoretically a measurement could be taken from anywhere within the central venous system which includes the superior vena cava and inferior vena cava within the thoracic cavity.[224,225] That would indicate that any lumen exiting within those vessels could be used for CVP's.

The superior vena cava averages 7cm in length.[223] Brandt found the length of the SVC varied with a range of 3cm to 10cm in a group of 50 patients he studied. He found the length of the SVC to be proportional to the height of the patient and it could be estimated by measuring the lower portion of the sternum.[33] Taking into consideration the spacing of the lumen exits on Arrow multiple lumen catheters (2.2cm), the amount of the distal catheter that must be within the SVC on a triple lumen catheter is 4.4cm. This length would fall within the SVC of most patients.

There is a lack of published data about using other lumens for CVP's. One small unpublished study that was performed using a heterogeneous group of 38 critical care patients demonstrated no significant difference between CVP's measured through the three lumens of a triple lumen catheter.[226] The measurements were taken from all three ports in succession with the patients supine at a 30° angle. The pressure transducer set up was recalibrated between port measurements. This study provides interesting results to support the theory that there is no significant difference between lumen CVP measurements, but further evaluation is needed.

problem *intervention*

Management of Occlusions

Catheter occlusion is a frequently encountered problem that is associated with most types of vascular access devices. An occlusion can be caused by a mechanical obstruction, a blood clot, chemical precipitate accumulation or lipid sludge build-up. In the past if the occlusion in a single lumen catheter could not be aspirated or the mechanical problem could not be corrected, the usual recourse was to change or remove the catheter. With multiple lumen catheters, when only one lumen became occluded, the same options were available but there was also a tendency to mark that lumen as blocked while the remaining lumen(s) continued to be used. This practice increases the risk of catheter-related infections and should be discouraged.

The first step in the evaluation of an occluded catheter is to determine whether there is a mechanical cause for the lack of flow, e.g. a kink in the tubing, a dry infusion bag or a positional

occlusion of the catheter. Measures should be taken to correct any mechanical problem. If the catheter remains occluded or no mechanical problem has been found, a thrombolytic agent or chemical compound can be used to "dissolve" the occlusion.

With the advent of thrombolytic agents, i.e. urokinase and streptokinase, and the discovery of the composition of chemical and lipid occlusions, catheters are being salvaged through the use of various declotting procedures. Urokinase,[233,235,244,245,249,252,253] streptokinase[243,247] and tissue plasminogen activator (t-PA)[230] have been successfully used to dissolve blood clots. Of these agents, urokinase 5000 IU/ml is used most frequently because it is less expensive than t-PA and does not cause allergic reactions as streptokinase does. The most frequently used procedure calls for the instillation of a volume of urokinase sufficient to fill the occluded lumen followed by a dwell time and repeated efforts to aspirate the clot at regular time intervals.[235,236,244] If the initial instillation does not open the lumen the process can be repeated again. It is important to remember that the older the occlusion the less responsive it will be to the therapy. If the lumen remains blocked after the additional instillations, an infusion of urokinase might be used[231,240] or the cause of the occlusions should be reevaluated to determine the benefit of using other agents.

As a prophylactic measure against central venous catheter thrombosis, Bern and associates evaluated the use of warfarin in low doses,[232] and found their regimen to be successful. For long term catheters the use of prophylactic doses of thrombolytic agents has also been discussed academically, but no studies have been published to document the efficacy of such a protocol.

When a thrombolytic agent fails to clear a catheter the reason for the failure might be that the occlusion is chemical in nature. Chemical occlusions can be caused by the infusion of poorly soluble components or incompatible medications. Chemical occlusions can often be solubized by introducing a compound that will alter the pH at the blockage site. An evaluation of the solutions that have been infused through the lumen will help to determine the course of action.

The agent that is used to lower the pH is a dilute solution of hydrochloric acid (HCl), 0.1N, in an amount necessary to fill the occluded lumen.[234,237,248,251] The HCl is allowed to dwell within the lumen for 20 minutes after which the patency of the lumen is checked. If the occlusion remains the process may be repeated twice. The only side effect of HCl administration that has been reported was fever that occurred as part of the Breaux study.[234] A possible explanation for the fever is that the HCl was infused systematically in that study and not confined to the catheter lumen.

The agent used to increase the pH within a lumen is sodium bicarbonate ($NaHCO_3$) in an 8.4% solution. As with the other procedures an amount is instilled equal to the filling volume of the catheter lumen and allowed a period of dwell time.[239,251] Usually the dissolution of a chemical occlusion occurs rapidly when the correct agent is used, and in the two reported uses of $NaHCO_3$ no additional instillations were necessary.

When lipids are infused a build-up of "lipid sludge" can cause catheter occlusion. The sludge consists of waxy lipid material that accumulates gradually on the surface of the catheter lumen. Catheters used for "all-in-one" solutions may be more prone to sludge development.[238] Incomplete occlusions of lipid sludge have been treated with success using a 70% solution of ethanol.[246] The ethanol was allowed to dwell for one hour and the catheters were then flushed and locked. In Pennington's study the ethanol was injected into silastic catheters without any effect on the catheter or patient. This is not the case when polyurethane catheters are used. **70% ethanol has been shown to reduce the tensile strength of Ar row polyurethane catheters when the conditions of clinical ethanol use have been simulated.** [229] Sodium hydroxide, 0.1N, has also been used for lipid occlusions,[250] but no information is currently available about its effects on polyurethane.

As an aid in determining what agent should be used to treat a central venous catheter occlusion, the algorithm developed by Holcombe, Forloines-Lynn and Garmhausen[242] is very useful. (See algorithm pages 124 and 125) The algorithm was developed for silastic, long-term central venous access devices so it does not caution about the use of ethanol in polyurethane catheters.

Declotting Guidelines:

- Prior to declotting verify catheter tip placement by chest x-ray.

- Rule out mechanical occlusion first.

- Evaluate medications infused through the line for possible clues about the nature of the occlusion.

- Use a 10cc syringe or larger to avoid excessive pressure.[92]

- Do not use excessive force during the declotting procedure.

- Use gentle aspiration to dislodge any occlusion.

- Do not exceed catheter lumen filling volume.

- Make sure the catheter is completely flushed out prior to trying another declotting agent.
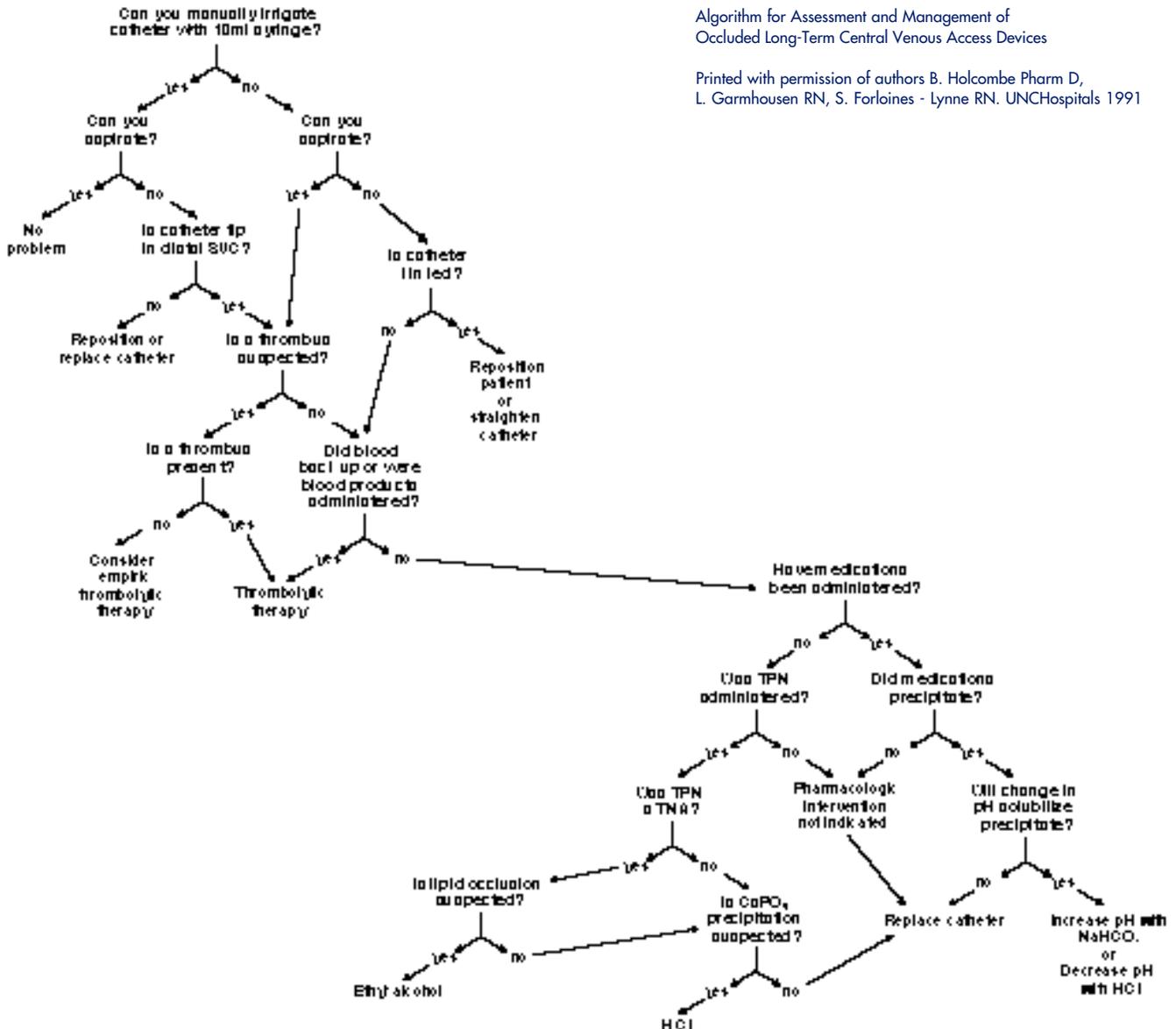
Catheter Repair

Damage to the catheter within the body cannot be repaired. Intraluminal damage in a multiple lumen catheter is also irreparable. In most cases the catheter must be removed because change over a guide wire would increase the risk for further catheter damage. The main focus of attention must be on prevention through proper catheter placement and the avoidance of excess intraluminal pressures and external stresses.

The internal (within the patient's bloodstream) or external (outside of the patient's body) portion of a central venous catheter can become damaged during catheter use. Internal damage can be related to catheter position. If the catheter has been placed in the subclavian vein and is pinched between the clavicle and the first rib the continued pressure (pinch-off syndrome) and shearing forces exerted on the catheter can cause partial or complete fracture of the catheter.[254] The catheter can also be damaged internally if too much force is exerted during a flushing procedure. If a catheter becomes partially fractured, the function of the catheter may be compromised, but a worse problem occurs if the catheter breaks completely and the broken segment embolizes within the heart or pulmonary artery. Patient symptoms will be dependent upon where the segment lodges.

The external portion of a catheter can be damaged when it is cut by a sharp instrument, such as scissors or a scalpel, clamped with a serrated edge clamp or when it is subjected to excess external force when snagged or pulled. If a break does occur, it is vital to clamp below the break to avoid having air enter the catheter.

Measures should be taken to avoid situations that would lead to catheter breakage; however, if a break occurs there are commercial kits available to repair central venous catheters. Temporary repair of a catheter does involve an amount of risk, and that risk must be carefully weighed when repair is considered an alternative to catheter exchange or removal. Arrow does not support this procedure or provide a repair kit for their products.

Algorithm for Assessment and Management of Occluded Long-Term Central Venous Access Devices

Printed with permission of authors B. Holcombe Pharm D, L. Garmhousen RN, S. Forloines - Lynne RN. UNCHospitals 1991

Algorithm for Assessment and Management of Occluded Long-Term Central Venous Access Devices

infection *control*

Health Care Workers

Due to the threat of exposure to blood during central venous catheter insertion and certain aspects of catheter care, all involved personnel must comply with the safety measures provided by using Universal Precautions. Protective garb and needlestick
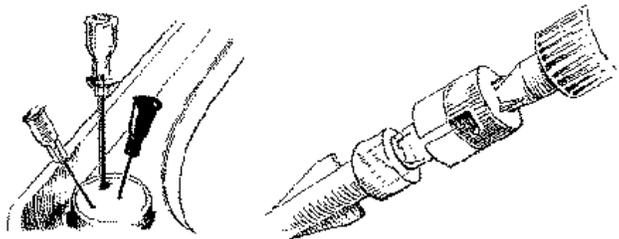
prevention measures should be utilized based on the task and amount of blood exposure that is anticipated. Needle free systems and needle containment devices have been developed to further reduce personnel exposure to needles during the admixture and administration of injectible medications. Systems for use with central venous catheters are available.

Patient

Routine measures as discussed throughout the booklet can be taken to reduce the risk of local and systemic catheter-related infections. They include hand washing, site preparation, catheter stabilization, occlusive dressings, site evaluation, minimal handling, set-up inspection and exchange, admixture precautions and inserter expertise.

In addition, advances designed to provide additional protection against catheter-related infection have been made in IV catheter technology, e.g. antiseptic-impregnated catheter materials, silver-impregnated collagen cuffs and antibiotic coated catheters. The action of these products is directed toward preventing the migration of skin micro-organisms down the catheter track.

ARROWg⁺ard™ is an antiseptic surface that has been shown in a large randomized clinical study by Maki to reduce the risk of catheter-related infection by 80%.[117] The antiseptic surface consists of a combination of silver-sulfadiazine and chlorhexidine that is impregnated into the polyurethane catheter surface. The agents act synergistically to prevent replication of microorganisms. The process involves alteration of the cell wall of the organism by chlorhexidine which then allows the entry of the silver ions into the cell. The silver ions bind to the DNA helix and prevent the cell from replicating.[256] Both agents are active against gram- positive and gram-negative bacteria as well as yeast. The agents are

released slowly over a period of time, up to 15 days, after which the release is reduced significantly.[255] By using a multiple lumen catheter made with the antiseptic surface, the benefits will include a longer catheter dwell time, decreased patient morbidity and mortality and cost effectiveness.

A similar principle was evaluated using the idea of antibiotic-coated central venous catheters. However, the use of antibiotics, usually ampicillin or a cephalosporin, raises the following concerns: there is a possibility that resistant microorganisms will develop with repeated antibiotic use, time must be spent to prepare the catheter for insertion and the agents used are not effective against yeasts.

A silver impregnated collagen cuff has also been shown to be effective in reducing the incidence of catheter-related infection. The cuff is attached to a catheter prior to insertion, and when the catheter is in position the cuff is inserted beneath the skin into the subcutaneous tissue. The cuff will become anchored in place by tissue growth into the collagen material, and silver ions are released from the cuff over time. This provides a physical barrier (collagen cuff) as well as antimicrobial action (silver ions) to prevent microorganism migration down the catheter.[114]

	Advantages	Disadvantages
Antiseptic surface (silver sulfadiazine/ chlorhexidine)	• Routine catheter • insertion technique • Synergistic activity of agents • Surface impregnation effective against bacteria and *Candida*	
Antibiotic coating	• Allows choice antibiotic	• Preparation of time prior to insertion • Possible emergence of resistant strains • Lack of action against Candida
Silver-impregnated collagen cuff	• Additional mechanical barrier	• Insertion technique

Combined with routine infection control measures, new IV technology such as ARROWgard™ can work to prevent the development of catheter-related infections in patients with central venous access. Measures such as these are important in all patients with multiple lumen catheters since they represent a compromised population in terms of morbidity and mortality.

catheter *exchange*

The amount of time a catheter remains in one site is a controversial issue. In hospitals a variety of protocols are followed including routine changes over a guide wire, routine changes to a new site and leaving the catheter in until complications occur or the catheter is no longer needed. There are pros and cons to all of these methods. Unfortunately, the studies that have been done to determine which protocol is best are difficult to compare due to their differences in target populations, change intervals, catheter types and other variables that are studied simultaneously, e.g., use of collagen cuffs.

The practice of routinely changing catheters, especially in the critical care setting, is the product of studies that have shown a direct relationship between increased catheter colonization/infection and the length of catheter indwelling time.[261,263,265,266,270] In response, many protocols have incorporated within them a catheter change every three to seven days either over a guide wire or into a new site to reduce the infection risk associated with prolonged catheterization.[257,259,264,267] However, the routine changing of catheters is not without risk.

Placing catheters in new sites has drawbacks that include the small number of sites available for rotation and the possibility of complications associated with each catheter insertion, such as air embolism malpositioning, pneumothorax and cardiac tamponade to name a few. A complication that can be associated with guide wire exchanges is colonization or infection. If the site is already colonized when a new catheter is inserted, colonization and future infection of the newly inserted catheter is almost ensured.[268] When the two methods for replacing catheters are compared, the problems associated with new insertions have caused some researchers to recommend guide wire exchanges instead of rotation to new sites.[269]

Recent studies have addressed the issue of routine replacement of catheters to assess the benefits of the procedure. In a study by Bonawitz, et al.,[258] three day catheter exchanges were compared to seven day exchanges. No statistically significant differences were noted between the patient groups in this prospective, randomized trial of critically ill subjects. Another study, by Cobb, et al.,[260] concluded that replacing catheters every three days does not

prevent infections in adult patients in ICU but does expose patients to complications associated with the changes. A third study by Eyer, et al.[262] that compared changes every seven days in surgical ICU patients also found no benefit to the procedure. The Cobb and Eyer studies led to conclusions on the part of the researchers that central venous catheters should be maintained using strict aseptic technique and should be allowed to remain in the same site unless removal is clinically indicated.

If the catheters are allowed to remain in one site, newer technologies such as an antiseptic impregnated catheter can offer further infection protection in addition to meticulous catheter care.

catheter *removal*

When a catheter is removed, precautions must be taken to prevent associated complications. During removal Universal Precautions must be employed to protect the health care worker from potential exposure to bloodborne pathogens. Aseptic technique must be used at the insertion site. To increase intra-thoracic pressure, the patient should be placed in Trendelenburg position, if tolerated, or flat in bed and should be instructed to hold his/her breath or perform the Valsalva maneuver. If the patient cannot cooperate with the instructions, the catheter should be removed during expiration.

After the catheter is removed pressure must be maintained with sterile gauze at the site until hemostasis is achieved, approximately five minutes. A totally air occlusive dressing must be placed over the insertion site to prevent an air embolism caused by air entering the body through the residual subcutaneous catheter track.[58,59,70,73,271] The dressing must remain in place for 24-72 hours depending on the length of time the catheter was indwelling. Dressing materials that have been suggested are Vaseline gauze[70,72,271] and telfa gauze with antimicrobial ointment.[72] The use of semipermeable membrane dressings has not been published in the literature, although they are used in some hospitals. Plain gauze with ointment is not acceptable as demonstrated in a case presented by Hanley.[58] In addition to the dressing, as further security the wound can be sutured closed.

During the time following catheter removal the patient should be observed closely for any signs and symptoms of complications, especially bleeding, air embolism or infection at the insertion site.

Removal Guidelines

- turn off all infusions
- wash hands
- don protective apparel according to Universal Precautions guidelines

- place patient in Trendelenburg or supine position

- instruct patient to perform Valsalva maneuver or hold breath on command

- if catheter cultures are collected have sterile field, sterile scissors and specimen containers available

- to collect catheter cultures the skin around the insertion site must be cleansed with an acceptable antiseptic, the catheter must be removed at a 90° angle from the skin and the desired segments (tip, subcutaneous) are cut with the sterile scissors and placed into the specimen containers

- as the catheter is removed the patient should perform the Valsalva maneuver or hold his/her breath

- immediately cover the insertion site with sterile gauze to apply pressure to the area

- cover the site with an occlusive dressing such as Vaseline gauze while the patient is performing the Valsalva maneuver or holding his/her breath

- leave occlusive dressing in place 24-72 hours depending upon the length of time the catheter was indwelling

- observe patient for complication signs and symptoms.

documentation

The following information should be included within the patient's chart:

- product name (refrain from misnomers, e.g. calling all thermodilution catheters a "Swan-Ganz", all tunneled catheters as "Hickman's")

- date of insertion, inserter

- anatomical location

- catheter depth according to catheter reference markings

- x-ray confirmation of catheter tip location

- port designation for infusions/measurements, e.g. TPN, CVP, medications

- amount, type and frequency of flush solution

- dressing and tubing changes

- site assessment, patient condition

- catheter guide wire exchanges

- complications

- catheter removal and application of air-impermeable dressing.

bibliography

General Information
1   Baranowski L. Central venous access devices. *J Intravenous Nurs.* 1993;16:167-194.
2   Farber BF. The multi-lumen catheter: proposed guidelines for its use. *Infect Control Hosp Epidemiol.* 1988;9:206-208.
3   Hadaway LC. Evaluation and use of advanced I.V. technology part 1: central venous access devices. *J Intravenous Nurs.* 1989;12:73-82.
4   Holder C, Alexander J. A new and improved guide to IV therapy. February 1990:43-47.
5   Jones S. New IV catheters that can do it all. *RN.* February 1985:2-5. Reprint.
6   Kaufman JL, Rodriguez JL, McFadden JA, Brolin RE. Clinical experience with the multiple lumen central venous catheter. *J Parenteral and Enteral Nutrition.* 1986;10:487-489.
7   Recker DH, Metzler DJ. Use of the multi-lumen catheter. *Crit Care Nurse.* May/June 1984:1-3.
8   Seneff M. Central venous catheters. In: Rippe JM, Irwin RS, Alpert JS, Fink MP, eds. *Intensive Care Medicine.* 2nd ed. Boston, Mass: Little Brown and Co; 1991:17-37.

Types of Catheters
9   Viall CD. Your complete guide to central venous catheters. *Nursing '90.* February 1990:34-41.

Catheter Materials and Properties
10 Crocker KS, Devereaux GB, Ashmore DL, Coker MH. Clinical evaluation of elastomeric hydrogel peripheral catheters during home infusion therapy. *J Intravenous Nurs.* 1990;13:89-97.
11 Dieckmann D. Plasticizers. In: Greene R, ed. *Modern Plastics Encyclopedia '92.* Hightstown, NJ: McGraw Hill; Mid-October 1991:184-187.
12 Frye RB. Silicones. In: Greene R, ed. *Modern Plastics Encyclopedia '92.* Hightstown, NJ: McGraw Hill; Mid-October 1991:138-141.
13 Gabbett JF. Introduction to PVC. In: Greene R, ed. *Modern Plastics Encyclopedia '92.* Hightstown, NJ: McGraw Hill; Mid-October 1991:122-123.
14 Gillis HR. Polyurethanes. In: Greene R, ed. *Modern Plastics Encyclopedia '92.* Hightstown, NJ: McGraw Hill; Mid-October 1991:135-138.
15 Schatten KL. Cardiovascular catheter polymer materials. *JVAN.* 1991;1:20-21.
16 Szycher M. *Biocompatible Polymers, Metals and Composites.* Lancaster, Pa: Technomic Publishing Co., Inc.; 1983.
17 Szycher M, Robinson, WJ. *Synthetic Biomedical Polymers: Concepts and Applications.* Lancaster, Pa: Technomic Publishing Co., Inc.; 1980.

Insertion Sites
18 Mallory D, Sapienza R, McGee WT, et al. "State-of-the-art" vascular cannulation in the ICU. *ResMedica.* 1988;4:5-14.
19 Seneff MG. Central venous catheterization: A comprehensive review, Part I. *J Intensive Care Medicine.* 1987;2:163-175.
20 Seneff MG. Central venous catheterization: A comprehensive review, Part II. *J Intensive Care Medicine.* 1987;2:218-232.

Site Preparation
21 Alexander JW, Fischer JE, Boyajian M, Palmquist J, Morris MJ. The influence of hair-removal methods on wound infections. *Arch Surg.* 1983;118:347.
22 Larson E. Guideline for use of topical antimicrobial agents. *Am J Infection Control.* December 1988;16:253-266.
23 LeVeen HH, LeVeen RF, LeVeen EG. The mythology of povidone-iodine and the development of self-sterilizing plastics. *Surg Gynecol Obstet.* 1993;176:183-190.
24 Maki D, Ringer M, Alvarado CJ. Prospective randomized trial of povidone-iodine, alcohol, and chlorhexidine for prevention of infection associated with central venous and arterial catheters. *Lancet.* August 1991; 338:339-343.
25 Strand CL, Wajsbort RR, Sturmann K. Effect of iodophor vs. iodine tincture skin preparation on blood culture contamination rate. *JAMA.* 1993;269:1004-1006.

Catheter Insertion
26 Conahan TJ III, Schwartz AJ, Geer RT. Percutaneous catheter introduction: the Seldinger technique. *JAMA.* 1977;237:446-447. Letter.
27 Daily EK, Schroeder JS. *Techniques in Bedside Hemodynamic Monitoring.* 4th ed. St. Louis, Mo: Mosby; 1989:59-62.
28 Jobes DR, Schwartz AJ, Greenhow DE, Stephenson LW, Ellison N. Safer jugular vein cannulation: recognition of arterial puncture and preferential use of the external jugular route. *Anesthesiology.* 1983;59:353-355.
29 Seldinger SI. Catheter replacement of the needle in percutaneous arteriography. *ACTA Radiologica.* 1953;39:368-376.
30 Sznajder J, Zveibil, F, Bitterman H, Weiner P, Bursztein S. Central vein catheterization. Failure and complication rates by three percutaneous approaches. *Arch Intern Med.* February 1986;146:259-261.

Catheter Tip Placement
31 Bar-Joseph G, Galvis AG. Perforation of the heart by central venous catheters in infants: guidelines to diagnosis and management. *J Pediatr Surg.* 1983;18:284-287.
32 Blitt CD, ed. *Monitoring in Anesthesia and Critical Care Medicine.* Central venous pressure monitoring. New York, NY: Churchill Livingstone; 1985:121-165.
33 Brandt RL, Foley WJ, Fink GH, Regan WJ. Mechanism of perforation of the heart with production of hydropericardium by a venous catheter and its prevention. *Am J Surg.* 1970;119:311-316.
34 Collier PE, Ryan JJ, Diamond DL. Cardiac tamponade from central venous catheters - report of a case and review of the English literature. *Angiology.* September 1984;35:595-600.
35 Curelaru J, Linder LE, Gustavsson B. Displacement of catheters inserted through internal jugular veins with neck flexion and extension. *Intens Care Med.* 1980;6:179-183.
36 Iberti TJ, Katz LB, Reiner MA, Brownie T, Kwun KB. Hydrothorax as a late complication of central venous indwelling catheters. *Surgery.* November 1983:842-846
37 Johans TG. Multiorificed catheter placement with an intravascular electrocardiographic technique . *Anesthesiology.* 1986;64:411-413. Letter.
38 Maschke SP, Rogove HJ. Cardiac tamponade associated with a multilumen central venous catheter . *Crit Care Med.* 1984;12:611-612.
39 McGee WT, Ackerman BL, Roubin LR, Prasad VM, Bandi V, Mallory DL. Accurate placement of central venous catheters: a prospective, randomized, multicenter trial. *Critical Care Medicine.* 1993;21:1118-1123.
40 Peters JL , ed. *A Manual of Central Venous Catheterization and Parenteral Nutrition.* Boston, Mass: John Wright PSG; 1983:58-61,155-157.
41 Sigurdsson J, Riba P, Sigurdsson S. The wandering central venous catheter . *Intensive Care Med.* 1985;11:263-264.
42 Tocino IM, Watanabe A. Impending catheter perforation of superior vena cava: radiographic recognition. *Am J Roentgenology.* March 1986;146:487-490.

Complications(General)
43 Beam TR, Goodman EL, Maki DG, Farr BM, Mayhall CG. Preventing central venous catheter-related complications, a roundtable discussion. *Infections in Surgery.* October 1990:1-13.
44 Collins JL. Central venous catheter complications. *Oncology. Nurs.Forum.* 1991;18:819-820. Letter.
45 Dawood MM, Trebbin WM. Complications associated with central venous cannulation. *Hosp Pract.* June 15, 1991;26:211-214,218-219.
46 Klass K. Troubleshooting central line complications. *Nursing 87.* November 1987:58-61.
47 Mihm FG, Rosenthal MH. Central venous catheterization. In: Benumof JL, ed. *Clinical Procedures in Anesthesia and Intensive Care.* Philadelphia, Pa: J B Lippincott Co; 1992:365-370.

[48] Parsa MH, Freeman HP. Precautions for long-term maintenance of central venous catheters: part I. *Surg Rounds.* November 1992:967-974.

[49] Richardson D, Bruso P. Vascular access devices - management of common complications. *J Intravenous Nurs.* 1993;16:44-49.

[50] Ryan JA, Gough J. Complication of central venous catheterization for total parenteral nutrition. *NITA.* 1984;7:29-35.

[51] Scott WL. Complications associated with central venous catheters. *Chest.* 1988;94:1221-1224.

[52] Wickham R, Purl S, Welker D. Long-term central venous catheters: issues for care. *Seminars in Oncology Nurs.* 1992;8:133-147.

[53] Wilson GL, McGregor PJ, Thompson GR. Long-term complications of intravascular cannulation. In: Venus B, Mallory DL, eds. *Problems in Critical Care.* Philadelphia, Pa: J.B. Lippincott Company; April-June 1988;2:296-313.

[54] Yerdel MA, Karayalcin K, Aras N, Bozatli L, Yildirim E, Anadol E. Mechanical complications of subclavian vein catheterization. A prospective study. *International Surgery.* 1991;76:18-22.

Air Embolism

[55] Alvaran SB, Toung JK, Graff TE, Benson DW. Venous air embolism: comparative merits of external cardiac massage, intracardiac aspiration, and left lateral decubitus position. *Anesth Analg.* 1978;57:166-170.

[56] Bedford RF. Venous air embolism: a historical perspective. *Seminars in Anesth.* September 1983;3:169-176.

[57] Coppa GF, Gouge TH, Hofstetter SR. Air embolism: a lethal but preventable complication of subclavian vein catheterization. *J Parenteral and Enteral Nutrition.* March/April 1981;5:166-168.

[58] Hanley PC, Click RL, Tancredi RG. Delayed air embolism after removal of venous catheters. *Ann Intern Med.* 1984;101:401-402. Letter.

[59] Kashuk JL, Penn I. Air embolism with venous catheterization. *Surg Gynecol Obstet.* 1984;159:249-252.

[60] Kondo K, O'Reily LP, Chiota J Jr. Air embolism associated with an introducer for pulmonary arterial catheters. *Anesth Analg.* 1984;63:871-872.

[61] McConnell EA. Preventing air embolism in patients with central venous catheters. *Nurs Life.* March/April 1986:47-49.

[62] Mendieta JM, Roy TM, Denny DM, Ossorio M. Venous air embolism associated with removal of central venous catheters. *J Kentucky Med Assoc.* April 1988; 86:169-173.

[63] Michel L, Poskanzer DC, McKusick KA, Nardi GL, Malt RA. Fatal paradoxical air embolism to the brain: complication of central venous catheterization. *J Parenteral and Enteral Nutrition.* January/February 1982;6:68-70.

[64] O'Quin RJ, Lakshminarayan S. Venous air embolism. *Arch Intern Med.* 1982;142:2173-2176.

[65] Ordway CB. Air embolus via CVP catheter without positive pressure: presentation of case and review. *Ann Surg.* April 1974;179:479-481.

[66] Orebaugh SL. Venous air embolism: clinical and experimental considerations. *Crit Care Med.* 1992;20:1169-1177.

[67] O'Rourke ME. Reducing the risk of venous air embolism. *Am J Nurs.* June 1988:886-890.

[68] Ostrow LS. Air embolism and central venous lines. *Am J Nurs.* 1981;81:2036-2038.

[69] Peters JL, Armstrong R, Bradford R, Gelister JK. Air embolism: a serious hazard of central venous catheter systems. *Intensive Care Med.* 1984;10:261-262.

[70] Phifer TJ, Bridges M, Conrad SA. The residual central venous catheter track - an occult source of lethal air embolism: case report. *J Trauma.* 1991;31:1558-1560.

[71] Seidelin PH, Stolarek IH, Thompson AM. Central venous catheterization and fatal air embolism. *Br J Hosp Med.* November 1987;438-439.

[72] Thielen JB. Air emboli: A potentially lethal complication of central venous lines. *Focus on Crit Care.* 1990;17:374-383.

[73] Thielen JB, Nyquist J. Subclavian catheter removal. *J Intravenous Nurs.* 1991;14:114-118.

[74] Turnage WS, Harper JV. Venous air embolism occurring after removal of a central venous catheter. *Anesth Analg.* 1991;72:559-560.

Cardiac Tamponade

[75] Chamsi-Pasha H, Waldek S. Cardiac tamponade complicating central venous catheter. *Postgrad Med J.* 1988;64:290-291.

[76] Csanky-Treels JC. Hazards of central venous pressure monitoring. *Anaesthesia.* 1978;33:172-177.

[77] Defalque RJ, Campbell C. Cardiac tamponade from central venous catheters. *Anesthesiology.* 1979;50:249-252.

[78] Edwards H, King TC. Cardiac tamponade from central venous catheters. *Arch Surg.* 1982;117:965-967.

[79] Eide J, Odegaard E. Cardiac tamponade as a result of infusion therapy. A potentially amenable complication of central venous catheters. *Acta Anaesthesiol Scand.* 1983;27:181-184.

[80] Estes MEZ. Management of the cardiac tamponade patient: a nursing framework. *Crit Care Nurse.* 1985;5:17-26.

[81] Fotre TV. Cardiac tamponade: early recognition and treatment. *Emerg Care Q.* 1988;4:19-28.

[82] Gordon HS. Action STAT - cardiac tamponade. *Nursing 86.* August 1986;33.

[83] Hancock EW. Cardiac tamponade. *Med Clin North Am.* January 1979;63:223-237.

[84] Hunt R, Hunter TB. Cardiac tamponade and death from perforation of the right atrium by a central venous catheter. *Amer J Roentgenology.* 1988;151:1250. Letter.

[85] Kapadia CB, Heard SO, Yeston NS. Delayed recognition of vascular complications caused by central venous catheters. *J Clin Monitoring.* 1988; 4:267-271.

[86] Long R, Kassum D, Donen N, DePape A, Taylor J, Warrian K. Cardiac tamponade complicating central venous catheterization for total parenteral nutrition: a review. *J Crit Care.* March 1987;2:39-44.

[87] Mitchell MR, Wood DG, Naraghi M, Riopelle JM. Fatal cardiac perforation caused by the dilator of a central venous catheterization kit. *J Clin Monitoring.* September 1993;9:288-291.

[88] Sheep RE, Guiney WB Jr. Fatal cardiac tamponade. *JAMA.* 1982;248:1632-1635.

[89] Suddleson EA. Cardiac tamponade: a complication of central venous hyperalimentation. *J Parenteral and Enteral Nutrition.* 1986;10:528-529.

[90] Timperman W, Rath R. Cardiac tamponade. *Contemporary Surg.* 1989;34:53-58.

[91] Thomas CS, Carter JW, Lowder SC. Pericardial tamponade from central venous catheters. *Arch Surg.* 1969;98:217-218.

Catheter Embolus/Rupture

[92] Conn C. The importance of syringe size when using implanted vascular access devices. *J Vasc Access Nurs.* Winter 1993;3:11-18.

[93] Cope C. Intravascular breakage of Seldinger spring wire guides. *JAMA.* June 23, 1962;180:1061-1063.

[94] Richardson JD, Grover FL, Trinkle JK. Intravenous catheter emboli. Experience with twenty cases and collective review. *Am J Surg.* 1974;128:722-727.

Arterial Puncture

[95] Todd MR, Barone JE. Recognition of accidental arterial cannulation after attempted central venipuncture. *Crit Care Med.* 1991;19:1081-1083.

Dysrhythmias

[96] Eissa NT, Kvetan V. Guide wire as a cause of complete heart block in patients with preexisting left bundle branch block. *Anesthesiology.* 1990;73:772-774.

[97] Kasten GW, Owens E, Kennedy D. Ventricular tachycardia resulting from central venous catheter tip migration due to arm position changes: report of two cases. *Anesthesiology.* 1985;62:185-187.

Nerve Injury

[98] Defalque RJ, Fletcher MV. Neurological complications of central venous cannulation. *J Parenteral and Enteral Nutrition.* 1988;12:406-409.

Catheter Malposition

[99] Gilner LI. The "ear-gurgling" sign. *NEJM.* 1977;296:1301. Letter.

[100] Jacobs WR, Zaroukian MH. Coughing and central venous catheter dislodgement. *J Parenteral and Enteral Nutrition.* August 1991;15:491-493.

[101] Lum PS, Soski M. Management of malpositioned central venous catheters. *J Intravenous Nursing.* December 1989;12:356-365.

[102] Rosa UW, Foreman M, Willsie-Ediger S. Intermittent back pain after central venous catheter placement. *J Parenteral and Enteral Nutrition.* 1993;17:91-93.

Pneumothorax, Hemothorax

[103] Maggs PR, Schwaber JR. Fatal bilateral pneumothoraces complicating subclavian vein catheterization. *Chest.* 1977;71:552-553.

[104] McGoon MD, Benedetto PW, Greene BM. Complications of percutaneous central venous catheterization: a report of two cases and review of the literature. *Johns Hopkins Med J.* July 1979;145:1-6.

Catheter-related Infection

[105] Beam TR, Goodman EL, Maki DG, Farr BM, Mayhall CG. Preventing central venous catheter-related complications. A roundtable discussion. *Infections in Surgery.* October 1990:1-13.

[106] Bjornsen HS. Pathogenesis, prevention and management of catheter-associated infections. *New Horizons.* May 1993;1:271-278.

[107] Bozzetti F. Central venous catheter sepsis. *Surg Gynecol Obstet.* September 1985;161:293-301.

[108] Corona ML Peters SG, Narr BJ, Thompson RL. Infections related to central venous catheters. *Mayo Clin Proc.* 1990;65:979-986.

[109] Dickinson GM, Bisno AL. Infections associated with indwelling devices: concepts of pathogenesis; infections associated with intravascular devices. *Antimicrobial Agents Chemother.* May 1989;33:597-601.

[110] Gil RT, Kruse JA, Thill-Baharozian MC, Carlson RW. Triple-vs single-lumen central venous catheters. *Arch Intern Med.* 1989;149:1139-1143.

[111] Goldmann DA. Coagulase-negative staphylococci: interplay of epidemiology and bench research. *Am J Infection Control.* June 1990;18:211-221.

[112] Hampton AA, Sherertz RJ. Vascular-access infections in hospitalized patients. *Surg Clin North Am.* 1988;68:57-71.

[113] Maki DG. Infections due to infusion therapy. In: Bennett JV, Brachman PS, eds. *Hospital Infections.* Boston, Mass: Little, Brown and Co; 1992:849-898.

[114] Maki DG, Cobb L, Garman JK, Shapiro JM, Ringer M. Helgerson RB. An attachable silver-impregnated cuff for prevention of infection with central venous catheters: a prospective randomized multicenter trial. *AJM.* September 1988;85:307-314.

[115] Maki DG, Ringer M. Evaluation of dressing regimens for prevention of infection with peripheral intravenous catheters: gauze, a transparent polyurethane dressing, and an iodophor-transparent dressing. *JAMA.* 1987;258:2396-2403.

[116] Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous-catheter-related infection. *NEJM.* 1977;296:1305-1309.

[117] Maki DG, Wheeler SJ, Stolz SM, Mermel LA. Clinical trial of a novel antiseptic-coated central venous catheter. Presented at 31st Interscience Conference on Antimicrobial Agents and Chemotherapy, Chicago, Ill, October 1, 1991. Abstract.

[118] Mermel LA, McCormick RD, Springman SR, Maki DG. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. *AJM.* September 1991;91 (Suppl. 3B):3B-197S-3B-205S.

[119] Miller JJ, Venus B, Mathru M. Comparison of the sterility of long-term central venous catheterization using single lumen, triple lumen, and pulmonary artery catheters. *Crit Care Med.* 1984;12:634-637.

[120] Norwood S, Hajjar G, Jenkins L. The influence of an attachable subcutaneous cuff for preventing triple lumen catheter infections in critically ill surgical and trauma patients. *Surg Gynecol Obstet.* July 1992;175:33-40.

[121] Norwood S, Ruby A, Civetta J, Cortes V. Catheter-related infections and associated septicemia. *Chest.* 1991;99:968-975.

[122] Passerini L, Lam K, Costerton JW, King EG. Biofilms on indwelling vascular catheters. *Crit Care Med.* 1992;20: 665-673.

[123] Powell C, Fabri PJ, Kudsk KA. Risk of infection accompanying the use of single-lumen vs double-lumen subclavian catheters: a prospective randomized study. *J Parenteral and Enteral Nutrition.* March/April 1988;12:127-129.

[124] Recker D. Catheter-related sepsis: an analysis of the research. *Dimensions of Crit Care Nurs.* Sept-Oct 1992;11:249-262.

[125] Rose SG, Pitsch RJ, Karrer W, Moor BJ. Subclavian catheter infections. *J Parenteral and Enteral Nutrition.* 1988;12:511-512.

[126] Snydman DR, Pober BR, Murray SA, Gorbea HF, Majka JA, Perry LK. Predictive value of surveillance skin cultures in total-parenteral-nutrition-related infection. *Lancet.* 1982;2:1385-1388.

[127] Toltzis P, Goldmann DA. Central venous catheter infections. *Infections in the Immunocompromised Host* (Burroughs Wellcome). 1986;4:2-11.

[128] Yeung C, May J. Hughes R. Infection rate for single lumen v triple lumen subclavian catheters. *Infect Control Hosp Epidemiol.* 1988;9:154-158.

Catheter-Related Thrombosis

[129] Curelaru I, Gustavsson B, Hultman E, et al. Material thrombogenicity in central venous catheterization III. A comparison between soft polyvinyl/chloride and soft polyurethane elastomer, long, antebrachial catheters. *Acta Anaesthesiol Scand.* 1984;28:204-208.

[130] Davis CL. Upper extremity venous thrombosis and central venous catheters. *Critical Care Nurse.* September 1991;11:16-22.

[131] Linder L-E, Curelaru I, Gustavsson B, Hansson H-A, Stenquist O, Wojciechowski J. Material thrombogenicity in central venous catheterization: a comparison between soft, antebrachial catheters of silicone elastomers and polyurethane. *J Parenteral and Enteral Nutrition.* August 1984;8:399-406.

[132] Stenqvist O, Curelaru I, Linder L-E. Gustavsson B. Stiffness of central venous catheters. *Acta Anaesthesiol Scand.* 1983;27;153-157.

[133] Williams EC. Catheter-related thrombosis. *Clin Cardiol.* 1990;13(suppl VI):VI34-36.

Hydrothorax/Vessel Erosion

[134] Duntley P, Siever J, Korwes ML, Harpel K, Heffner JE. Vascular erosion by central venous catheters. *Chest.* 1992;101:1633-1638.

[135] Ellis LM, Vogel SB, Copeland EM III. Central venous catheter vascular erosions. *Ann Surg.* 1989;209:475-478.

CATHETER MAINTENANCE

Dressings

[136] Aly R, Shirley C, Cunico B, Maibach HI. Effect of prolonged occlusion on the microbial flora, pH, carbon dioxide and transepidermal water loss on human skin. *J Invest Dermatol.* 1978;71:378-381.

[137] Conly JM, Grieves K, Peters B. A prospective, randomized study comparing transparent and dry gauze dressings for central venous catheters. *J Infectious Diseases.* February 1989;159:310-319.

[138] Craven DE, Lichtenberg DA, Kunches LM, et al. A randomized study comparing a transparent polyurethane dressing to a dry gauze dressing for peripheral intravenous catheter sites. *Infection Control.* 1985;6:361-366.

[139] Eisenberg PG, Howard MP, Gianino MS. Improved long-term maintenance of central venous catheters with a new dressing technique. *J Intravenous Nurs.* 1990;13:279-284.

[140] Gantz NM, Presswood GM, Goldberg R. Doern G. Effects of dressing type and change interval on intravenous therapy complication rates. *Diagn Microbiol Infect Dis.* 1984;2:325-332.

[141] Hoffmann KK, Weber DJ, Samsa GP, Rutala WA. Transparent polyurethane film as an intravenous catheter dressing. *JAMA.* 1992;267:2072-2076.

[142] Hoffmann KK, Western SA, Kaiser DL, Wenzel RP, Groschel DHM. Bacterial colonization and phlebitis-associated risk with transparent polyurethane film for peripheral intravenous site dressings. *Am J Infection Control.* June 1988;16:101-106.

[143] Lawson M, Kavanagh T, McCredie K, Marts K, Barbour N, Chandler W. Comparison of transparent dressing to paper tape dressing over central venous catheter sites. *NITA.* January/February 1986;9:40-43.

[144] Maki DG, Stolz S, Wheeler S. A prospective, randomized, three-way clinical comparison of a novel, highly permeable, polyurethane dressing with 206 Swan-Ganz pulmonary artery catheters: OpSite IV 3000 vs. Tegaderm vs. gauze and tape. In: Maki DG, ed. *Improving Catheter Site Care.* Royal Society of Medicine Services International Congress and Symposium Series No. 179, Royal Society of Medicine Services Limited. London;1991:61-66.

145 Palidar PJ, Simonowitz DA, Oreskovich MR, et al. Use of OpSite as an occlusive dressing for total parenteral nutrition catheters. *J Parenteral and Enteral Nutrition.* 1982;6:150-151.

146 Powell C, Regan C, Fabri PJ, Ruberg RL. Evaluation of OpSite catheter dressings for parenteral nutrition: a prospective, randomized study. *J Parenteral and Enteral Nutrition.* 1982;6:43-46.

147 Shivnan JC, McGuire D, Freedman S, et al. A comparison of transparent adherent and dry sterile gauze dressings for long-term central catheters in patients undergoing bone marrow transplant. *Oncology Nurs Forum.* 1991;18:1349-1356.

Defatting the Skin
148 Maki D, McCormack KN. Defatting catheter insertion sites in total parenteral nutrition is of no value as an infection control measure. *Am J Med.* 1987;83:833-840.

149 Rothman S, Lorincz AL. Defense mechanisms of the skin. *Annual Rev Med.* 1963;14:215-242.

Antimicrobial Ointment
150 Hill RLR, Fisher AP, Ware RJ, Wilson S, Casewell MW. Mupirocin for the reduction of colonization of internal jugular cannulae - a randomized controlled trial. *J Hospital Infection.* 1990;15:311-321.

151 Levy RS, Goldstein J, Pressman RS. Value of a topical antibiotic ointment in reducing bacterial colonization of percutaneous venous catheters. *J Albert Einstein Med Center.* Summer, 1970;18:67-70.

152 Maki DG, Band JD. A comparative study of polyantibiotic and iodophor ointments in prevention of vascular catheter-related infection. *Am J Med.* 1981;70:739-744.

Delivery System
153 Band JD, Maki DG. Safety of changing intravenous delivery systems at longer than 24-hour intervals. *Ann Intern Med.* 1979;91:173-178.

154 Buxton AE, Highsmith AK, Garner JS, et al. Contamination of intravenous infusion fluid: effects of changing administration sets. *Ann Intern Med.* 1979;90:764-768.

155 Gorbea HF, Snydman DR, Delaney A, Stockman J, Martin WJ. Intravenous tubing with burettes can be safely changed at 48-hour intervals. *JAMA.* 1984;251:2112-2115.

156 Josephson A, Gombert ME, Sierra MF, Karanfil LV, Tansino GF. The relationship between intravenous fluid contamination and the frequency of tubing replacement. *Infection Control.* 1985;6:367-370.

157 Maki DG, Botticelli JT, LeRoy ML, Thielke TS. Prospective study of replacing administration sets for intravenous therapy at 48- vs. 72-hour intervals. *JAMA.* 1987;258:1777-1781.

158 Simmons BP. Guideline for prevention of intravenous therapy-related infections. In: *Guideline for Prevention of Intravascular Infections.* Centers for Disease Control, Atlanta, Ga: October 1981.

159 Snydman DR, Donnelly-Reidy M, Perry LK, Martin WJ. Intravenous tubing containing burettes can be safely changed at 72 hour intervals. *Infection Control.* 1987;8:113-116.

Slide Clamps
160 Arrow International, data on file.

Primary Injection Sites
161 Arrow International, data on file.

Maintaining Patency
162 American Association of Critical Care Nurses. Evaluation of the effects of heparinized and nonheparinized flush solutions on the patency of arterial pressure monitoring lines: the AACN Thunder Project. *Amer J Crit Care.* 1993;2:3-15.

163 American Association of Critical Care Nurses. Nationwide practice survey results announced. *AACN News.* August 1990:3.

164 Anderson KM, Holland JS. Maintaining the patency of peripherally inserted central catheters with 10 Units/cc heparin. *J Intravenous Nurs.* March/April 1992;15:84-88.

165 Ashton J, Gibson V, Summers S. Effects of heparin versus saline solution on intermittent infusion device irrigation. *Heart Lung.* 1990;19:608-612.

166 Baldwin DR. Heparin-induced thrombocytopenia. *J Intravenous Nurs.* 1989;12:378-382.

167 Barrett PJ, Lester RL. Heparin versus saline flushing solutions in a small community hospital. *Hosp Pharmacy.* February 1990;25:115-118.

168 Chang JC. White clot syndrome associated with heparin-induced thrombocytopenia: a review of 23 cases. *Heart Lung.* July 1987;16:403-407.

169 Cyganski JM, Donahue JM, Heaton JS. The case for the heparin flush. *Am J Nurs.* June 1987:796-797.

170 Deeb EN, DiMattia PE. The key question: how much heparin in the lock? *Amer J IV Therapy.* December/January 1976:22-26.

171 Doty JR, Alving BM, McDonnell DE, Ondra SL. Heparin-associated thrombocytopenia in the neurosurgical patient. *Neurosurgery.* July 1986;19:69-72.

172 Dunn DL, Lenihan SF. The case for saline flush. *Am J Nurs.* June 1987:798-799.

173 Epperson EL. Efficacy of 0.9% sodium chloride injection with and without heparin for maintaining indwelling intermittent sites. *Clin Pharmacy.* November/December 1984;3:626-629.

174 Fry B. Intermittent heparin flushing protocols. *J Intravenous Nurs.* 1992;15:160-163.

175 Garrelts JC, LaRocca J, Ast D, Smith DF, Sweet DE. Comparison of heparin and 0.9% sodium chloride injection in the maintenance of indwelling intermittent i.v. devices. *Clin Pharmacy.* 1989;8:34-39.

176 Geritz, MA. Saline versus heparin in intermittent infuser patency maintenance. *West J Nurs Research.* 1992;14:131-141.

177 Goode CJ, Titler M, Rakel B, et al. A meta-analysis of effects of heparin flush and saline flush: quality and cost implications. *Nurs Research.* November/December 1991;40:324-330.

178 Hamilton RA, Plis JM, Clay C, Sylvan L. Heparin sodium versus 0.9% sodium chloride injection for maintaining patency of indwelling intermittent infusion devices. *Clin Pharmacy.* 1988;7:439-443.

179 Harrigan CA. Intermittent I.V. therapy without heparin: a study. *NITA.* November/December 1985;8:519-520.

180 Hanson RL, Grant AM, Majors KR. Heparin-lock maintenance with ten units of sodium heparin in one milliliter of normal saline solution. *Surg Gynecol Obstet.* 1976;142:373-376.

181 Heeger PS, Backstrom JT. Heparin flushes and thrombocytopenia. *Ann Intern Med.* 1986;105:143.

182 Intravenous Nurses Society. Intravenous nursing standards of practice. *J Intravenous Nurs.* 1990; 13 (suppl):S1-S98.

183 Irvin S. White clot syndrome: a life-threatening complication of heparin therapy. *Focus on Crit Care.* April 1990;17:107-110.

184 King DJ, Kelton JG. Heparin-associated thrombocytopenia. *Ann Intern Med.* 1984;100:535-540.

185 Kuc JA. When heparin causes clots. *RN.* March 1993;34-37.

186 Laster JL, Nichols K, Silver D. Thrombocytopenia associated with heparin-coated catheters in patients with heparin-associated antiplatelet antibodies. *Arch Intern Med.* 1989;149:2285-2287.

187 Miller ML. Heparin-induced thrombocytopenia. *Cleveland Clin J Med.* July/August 1989;56:483-490.

188 Passanante A, Macik BG. Case report: the heparin flush syndrome: a cause of iatrogenic hemorrhage. *Am J Med Sciences.* July 1988;296:71-73.

189 Peterson FY, Kirchhoff KT. Analysis of the research about heparinized versus nonheparinized intravascular lines. *Heart Lung.* 1991;20:631-642.

190 Ridley PA, Dean TW. The use of unpreserved 0.9% sodium chloride injection for the maintenance of multilumen subclavian catheters. *CINA.* January/March 1990;6:5,8-9.

191 Rizzoni WE, Miller K, Rick M, Lotze MT. Heparin-induced thrombocytopenia and thromboembolism in the postoperative period. *Surgery.* April 1988;103:470-476.

192 Schwartz BS. Heparin: what is it? how does it work? *Clin Cardiol.* 1990;13:VI-12-15.

193 Shearer J. Normal saline flush versus dilute heparin flush. *NITA.* November/December 1987:425-427.

194 Taylor N. Hutchison E, Milliken W, Larson E. Comparison of normal versus heparinized saline for flushing infusion devices. *J Nurs Qual Assur.* 1989;3:49-55.

195 Tuten SH, Gueldner SH. Efficacy of sodium chloride versus dilute heparin for maintenance of peripheral intermittent intravenous devices. *Applied Nurs Research.* May 1991;4:63-71.

196 Warkentin TE, Kelton JG. Heparin-induced thrombocytopenia. *Ann Rev Med.* 1989;40:31-44.

Blood Sampling
197 Almadrones L, Godbold J, Raaf J, Ennis J. Accuracy of activated partial thromboplastin time drawn through central venous catheters. *Oncol Nurs Forum.* 1987;14:15-18.

198 Bodai BI, Holcroft JW. Reply to letter re: Use of the pulmonary arterial catheter in the critically ill patient. *Heart Lung.* 1983;12:329.

199 Bryant JK, Strand CL. Reliability of blood cultures collected from intravascular catheter versus venipuncture. *Am J Clin Pathol.* 1987;88:113-116.

200 Chernow B, Salem M, Stacey J. Blood conservation - a critical care imperative. *Crit Care Med.* 1991;19:313-314. Editorial.

201 Clapham MCC, Willis N, Mapleson WW. Minimum volume of discard for valid blood sampling from indwelling arterial cannulae. *Br J Anaesth.* 1987;59:232-235.

202 Cook JD, Koch TR, Knoblock EC. Erroneous electrolyte results caused by catheters. *Clin Chem.* 1988;34:211. Letter.

203 Crocker, KS. *Multilumen Central Venous Catheters. Nursing Care Policies and Guidelines.* Reading, PA; Arrow International, Inc. Educational Pamphlet

204 Dryden GE, Brickler J. Stopcock contamination. *Anesth Analg.* March/April 1979;58:141-142.

205 Eyster E, Bernene J. Nosocomial anemia. *JAMA.* 1973;223:73-74.

206 Foulke GE, Harlow DJ. Effective measures for reducing blood loss from diagnostic laboratory tests in intensive care unit patients. *Crit Care Med.* 1989;17:1143-1145.

207 Gregerson RA, Underhill SL, Detter JC, Schmer G, Lax K. Accurate coagulation studies from heparinized radial artery catheters. *Heart Lung.* November 1987;16:686-693.

208 Jackson EF. The reliability of blood tests drawn from intravenous lines. *Ohio State Med J.* January 1972:32-35.

209 Johnston JB, Messina M. Erroneous laboratory values obtained from central catheters. *J Intravenous Nurs.* January/February 1991;14:13-15.

210 Lew JKL, Hutchinson R, Lin ES. Intra-arterial blood sampling for clotting studies. *Anaesthesia.* 1991;46:719-721.

211 Molyneaux RD Jr, Papciak B, Rorem DA. Coagulation studies and the indwelling heparinized catheter. *Heart Lung.* 1987;16:20-23.

212 Palermo LM, Andrews RW, Ellison N. Avoidance of heparin contamination in coagulation studies drawn from indwelling lines. *Anesth Analg.* 1980;59:222-224.

213 Reinhardt ACR, Tonneson AS, Bracey A, Goodnough SKC. Minimum discard volume from arterial catheters to obtain coagulation studies free of heparin effect. *Heart Lung.* 1987;16:699-705.

214 Smoller BR, Kruskall MS. Phlebotomy for diagnostic laboratory tests in adults. *N Engl J Med.* 1986;314:1233-1235.

215 Templin K, Shively M, Riley J. Accuracy of drawing coagulation samples from heparinized arterial lines. *Am J Crit Care.* 1993;2:88-95.

216 Weinstein SM. *Plumer's Principles and Practice of Intravenous Therapy.* 5th ed. Philadelphia, Pa: JB Lippincott Co;1993:233-239.

INFUSIONS

Incompatible Infusions
217 Bell RM, Record K. Clinical Evaluation of the Arrow-Howes Multi-lumen Central Venous Catheter. Arrow International, data on file.

218 Collins JL, Lutz RJ. In vitro study of simultaneous infusion of incompatible drugs in multilumen catheters. *Heart Lung.* 1991;20:271-277.

219 Davie IT. Specific drug interactions in anaesthesia. *Anaesthesia.* 1977;32:1000-1008.

220 Klein DG. The multilumen central venous catheter. *J Burn Care Rehabil.* May/June 1984;5:236-238.

221 Peterson FB, Clift R, Buckner CD, Sanders JE, Hickman R, Meyers J. Design and use of double lumen right atrial catheters in bone marrow transplant recipients. *Acta Anaesth Scand.* 1985;81(suppl):16-19.

222 Trissel LA. *Handbook on Injectable Drugs.* 6th ed. Bethesda, Md: American Society of Hospital Pharmacists; 1990.

Monitoring
223 Clemente CD, ed. *Gray's Anatomy.* 30th ed. Philadelphia, Pa: Lea & Febiger;1985:799.

224 Johnson MS. Nurses' guide to central venous pressure monitoring. *Military Medicine.* February 1970:100-106.

225 Maier WP, Goldman LI, Rosemund GP. Central venous pressure monitoring. *Pennsylvania Medicine.* February 1969:58-61.

226 Russo PR. *Comparison of Central Venous Pressures through the Three Ports of the Triple Lumen Catheter.* Houston, Tex: The University of Texas Health Science Center at Houston; 1991. Thesis.

227 Schwenzer KJ. Venous and pulmonary pressures. In: Lake CL. *Clinical Monitoring.* Philadelphia, Pa: WB Saunders; 1990:147-152.

228 Yacone LA. Monitoring central venous pressure. In: Darovic GO. *Hemodynamic Monitoring.* Philadelphia, Pa: WB Saunders Co; 1987:115-135.

Management of Occlusions
229 Arrow International, data on file.

230 Atkinson JB, Bagnall HA, Gomperts E. Investigational use of tissue plasminogen activator (t-PA) for occluded central venous catheters. *J Parenteral and Enteral Nutrition.* May/June 1990;14:310-311.

231 Bagnall HA, Gomperts E, Atkinson JB. Continuous infusion of low-dose urokinase in the treatment of central venous catheter thrombosis in infants and children. *Pediatrics.* 1989;83:963-966.

232 Bern MM, Lokich JJ, Wallach SR, et al. Very low doses of warfarin can prevent thrombosis in central venous catheters. *Ann Intern Med.* 1990;112:423-428.

233 Bjeletich J. Declotting central venous catheters with urokinase in the home by nurse clinicians. *NITA.* November/December 1987:428-430.

234 Breaux CW Jr, Duke D, Georgeson KE, Mestre JR. Calcium phosphate crystal occlusion of central venous catheters used for total parenteral nutrition in infants and children: prevention and treatment. *J Pediatr Surg.* 1987;22:829-832.

235 Brown LH, Wantroba I, Simonson G. Reestablishing patency in an occluded central venous access device. *Crit Care Nurs.* 1989;9:114-121.

236 Cunliffe MT, Polomano RC. How to clear catheter clots with urokinase. *Nursing 86.* December, 1986. Reprint.

237 Duffy LF, Kerzner B, Gebus V, Dice J. Treatment of central venous catheter occlusions with hydrochloric acid. *J Pediatr.* 1989;114:1002-1004.

238 Freund HR, Rimon B, Muggia-Sullam M, Gimmon Z. The "all in one" system for TPN causes increased rates of catheter blockade. *J Parenteral and Enteral Nutrition.* September/October 1986;543.

239 Goodwin ML. Using sodium bicarbonate to clear a medication precipitate from a central venous catheter. *JVAN.* Winter 1991;1:23.

240 Haire WD, Lieberman RP, Lund GB, Edney J. Wieczorek BM. Obstructed central venous catheters. *Cancer.* 1990;66:2279-2285.

241 Hickman J, Danek G, Smith D. Use of intravenous sodium bicarbonate to clear occluded central venous catheters. Presented at the 15th ASPEN Clinical Congress; January 27-31, 1991; San Francisco, Calif. Abstract.

242 Holcombe BJ, Forloines-Lynn S, Garmhausen LW. Restoring patency of long-term central venous access devices. *J Intravenous Nurs.* January/February 1992;15:36-41.

243 Hurtubise MR, Bottino JC, Lawson M, McCredie KB. Restoring patency of occluded central venous catheters. *Arch Surg.* February 1980;115:212-213.

244 Lawson M. Partial occlusion of indwelling central venous catheters. *J Intravenous Nurs.* May/June 1991;14:157-159.

245 Monturo CA, Dickerson RN, Mullen JL. Efficacy of thrombolytic therapy for occlusion of long-term catheters. *J Parenteral and Enteral Nutrition.* 1990;14:312-314.

246 Pennington R, Pithie AD. Ethanol lock in the management of catheter occlusion. *J Parenteral and Enteral Nutrition.* 1987;11:507-508.

247 Schneider TC, Krzywda E, Andris D, Quebbeman EJ. The malfunctioning silastic catheter - radiologic assessment and treatment. *J Parenteral and Enteral Nutrition.* January/February 1986;10:70-73.

248 Shulman RJ, Reed T, Pitre D, Laine L. Use of hydrochloric acid to clear obstructed central venous catheters. *J Parenteral and Enteral Nutrition.* 1988;12:509-510.

249 Suarez CR, Ow EP, Lambert GH, Anderson CL, Purewal NS. *Amer J Hematology.* 1989;31:269-272.

250 ter Borg F, Timmer J, de Kam SS, Sauerwein HP. Use of sodium hydroxide solution to clear partially occluded vascular access ports. *J Parenteral and Enteral Nutrition.* 1993;17:289-291.

251 Testerman EJ. Restoring patency of central venous catheters obstructed by mineral precipitation using hydrochloric acid. *JVAN*. Winter 1991;1:22-23.
252 Wachs T. Urokinase administration in pediatric patients with occluded central venous catheters. *J Intravenous Nurs*. 1990;13:100-102.
253 Winthrop AL, Wesson DE. Urokinase in the treatment of occluded central venous catheters in children. *J Ped Surg*. October 1984;19:536-538.

Catheter Repair
254 Hinke DH, Zandt-Stastny DA, Goodman LR, Quebbeman EJ, Krzywda EA, Andris DA. Pinch-off syndrome: a complication of implantable subclavian venous access devices. *Radiology*. November 1990;177:353-356.

Infection Control
255 Farber T. *ARROWgard Antiseptic Surface - Toxicology Review*. Monograph. Reading, PA: Arrow International, Inc. 1992.
256 Modak SM, Sampath L. Development and evaluation of new polyurethane central venous antiseptic catheter: reducing central venous catheter infections. *Infections in Medicine*. June 1992:23-29.

Catheter Exchange
257 Bonadimani B, Sperti C, Stevanin A, et al. Central venous catheter guidewire replacement according to the Seldinger technique: usefulness in the management of patients in total parenteral nutrition. *J Parenteral and Enteral Nutrition*. 1987;11:267-270.
258 Bonawitz SC, Hammell EJ, Kirkpatrick JR. Prevention of central venous catheter sepsis: a prospective randomized trial. *Am Surgeon*. October 1991;57:618-623.
259 Bozzetti F, Terno G, Bonfanti G, et al. Prevention and treatment of central venous catheter sepsis by exchange via a guidewire. *Ann Surg*. July 1983;48-52.
260 Cobb DK, High KP, Sawyer RG, et al. A controlled trial of scheduled replacement of central venous and pulmonary-artery catheters. *N Engl J Med*. 1992;327:1062-1068.
261 Cronin WA, Germanson TP, Donowitz LG. Intravascular catheter colonization and related bloodstream infection in critically ill neonates. *Infect Control Hosp Epidemiol*. 1990;11:301-308.
262 Eyer S, Brummitt C, Crossley K. Siegel R, Cerra F. Catheter-related sepsis: prospective, randomized study of three methods of long-term catheter maintenance. *Crit Care Med*. 1990;18:1073-1079.
263 Gil RT, Kruse JA, Thill-Baharozian MC, Carlson RW. Triple-vs single-lumen central venous catheters. *Arch Intern Med*. 1989;149:1139-1143.
264 Hagley MT, Martin B, Gast P, Traeger SM. Infectious and mechanical complications of central venous catheters placed by percutaneous venipuncture and over guidewires. *Crit Care Med*. 1992;20:1426-1430.
265 Maki DG, Will L. Risk factors for central venous catheter-related infection within the ICU. A prospective study of 345 catheters. Presented at the 3rd International Conference on Nosocomial Infections; 1990; Atlanta, Ga. Abstract.
266 Michel L, Marsh HM, McMichan JC, Southorn PA, Brewer NS. Infection of pulmonary artery catheters in critically ill patients. *JAMA*. 1981;245:1032-1036.
267 Norwood S, Jenkins G. An evaluation of triple-lumen catheter infections using a guidewire exchange technique. *J Trauma*. 1990;30:706-712.
268 Olson ME, Lam K, Bodey GP, King EG, Costerton JW. Evaluation of strategies for central venous catheter replacement. *Crit Care Med*. 1992;20:797-804.
269 Snyder RH, Archer FJ, Endy T, et al. Catheter infection. *Ann Surg*. 1988;208:651-653.
270 Ullman RF, Gurevich I, Schoch PE, Cunha BA. Colonization and bacteremia related to duration of triple-lumen intravascular catheter placement. *Am J Infection Control*. 1990;80:201-207.

Catheter Removal
271 Paskin DL, Hoffman WS, Tuddenham WJ. A new complication of subclavian vein catheterization. *Ann Surg*. March 1974;179:266-268.
272 Raad II, Hohn DC, Gilbreath BJ, et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infect Control Hosp. Epidemiol*. 1994;15:231-238.

Misunderstanding

Morning rounds, the intern's order

DiscontinueTLC

a word and three letters puzzling to me,
displayed so near approaching death and this cold
robot of volume and flow quantitating every breath.
How inappropriate, it seems, to discontinue *tender loving care* for this spare woman scored with tears–
strange enough for me,
embarrassed to inquire of love with a stethoscope
tickling my ears,
to ask her nurse the meaning of this doctor's order.

Oh, she reported, that's *Triple-Lumen Catheter* in this ICU.

So, now I understand the meaning of TLC in room 262, where we are headed this morning, what a difference three letters can make,
how much the language of this work has changed.

Eric L. Dyer, M.D., Nashville, Tennessee

as printed in the April 15, 1993 issue of *Annals of Internal Medicine*

Printed with permission of author.