VENOUS ACCESS

Coordinator: Donald Denny, MD, FSIR,

Faculty:
Joseph Bonn MD, FSIR
Brad Glenn, MD
Sohail Contractor, MD

Primary contributors to workshop handout: Don Denny, MD, Thomas Vesely, MD, David J. Eschelman, MD, Jeffrey S. Pollak, MD, Mel Rosenblatt, MD. Edited by Howard Chrisman, MD, Thomas Vesely, MD and Don Denny, MD

Pearls:

1. "Physician extenders" such as nurse practitioners, physician assistants, and radiology assistants are assuming more responsibility for the insertion and management of central venous catheters and ports.
2. There are polyurethane PICCs specially approved for use with power injectors at flow rates up to 5 ml/s.
3. Chest and arm ports approved for use with contrast power injectors are also now available.
4. Skin glue, 2-octyl cyanoacrylate can be used to assist in skin closure, speeding closure and providing a watertight dressing.
5. A method for inserting a tunneled jugular catheter with a single incision and puncture from an infraclavicular approach has been reported.
6. Chlorhexidine gluconate has replaced betadine as the preferred cleansing agent for intact skin (CDC guidelines).
7. Location, location, location. The right internal jugular vein is the preferred site for the majority of central venous catheters (K/DOQI).
8. New developments in catheter coatings, including antibiotic-impregnated and antithrombotic coatings may reduce the incidence of catheter-related infection in longer term catheters, such as tunneled hemodialysis catheters. This is work in progress.

Suggested use of this handout:

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Catheter Choice: Clinical Perspective

Introduction:

In patients requiring circulatory access for therapy the first step in their treatment is choosing the appropriate access device. This seemingly simple task is deceptively complex. Ideally, an access device should provide reliable complication free circulatory access. Since this ideal device does not exist it is left up to the clinician to choose a device that will match the patient's particular clinical needs. To do this, one must be familiar with the variety of access devices available and understand their clinical design limitations. In this presentation, we review the available access devices, the biomaterials used in their construction and highlight the clinical issues related to device selection.

"The Ideal Access Device": Device Limitations

The ideal access device would provide reliable complication free circulatory access. Unfortunately, no such device exists. Complications related to central venous access are frequent. These complications

include periprocedural complications, thrombotic complications, infectious complications, and device malfunction [1, 2]. In designing devices to reduce complications and enhance function, there is often a trade-off that must be made. As an example, central venous thrombosis which is the result of the long-term presence of a catheter in a vascular system can be reduced by utilizing catheters of small diameter [3, 4]. Unfortunately, small diameter catheters having a single lumen, cannot sustain high flow rates and often fail prematurely due to catheter occlusion. This same limitation applies to peripherally implanted devices. These devices were designed to avoid complications such as pneumothorax, inadvertent arterial puncture, vascular injury, and air embolus, which are all associated with access into a central vein. Peripheral veins, however, are small and only small diameter catheters, with their inherent limitations, can be accommodated. Another example involves infectious complications, which are, by far, the most common complications associated with central venous access. These complications are the result of inadvertent bacterial introduction and subsequent bacterial adherence to the inert catheter material which is present in the vascular system. The ideal access device would be impervious to infection. In the absence of such a device, manufactures have modified device designs to help reduce the incidence of infectious complications[5]. Unfortunately, these modifications have their disadvantages. Subcutaneously implanted devices are an example of such a modification. These devices have no external components and thus have a reduced incidence of infection[6]. However, they are far more expensive than devices that have external components, are more difficult to place, and can not sustain high blood flow rates. Device infection, when it occurs, may be masked until infection becomes severe. Many other such trade-offs exist. Each device has its advantages and disadvantages. A basic understanding of device construction and thorough knowledge of the various available access devices is the critical first step in selecting an appropriate access device.

Materials Used in Access Device Construction:

Currently, all chronic access catheters are constructed from one of two different materials, polyurethane or silicone. Each of these materials has different characteristics which have clinical impact. Polyurethane is a block copolymer that contains high molecular weight macroglycols linked together by a urethane group. This material is produced by the rearrangement polymerization of diisocyanate and macroglycols [7]. Polyurethane has a high tensile strength permitting catheters to be constructed with relatively thin walls. This permits the catheter to have a high internal diameter to outer diameter ratio. A variety of different biomedical polyurethanes, with varying properties, are produced. Unfortunately, many of these polyurethanes are unavailable for use in the production of chronic venous access catheters. Two types, Chronoflex and Tecoflex, are the most commonly encountered chronic catheter polyurethanes.

One major disadvantages of all polyurethanes is Environmental Stress Cracking (ESC). As its name suggests, ESC leads to mircocracks in the material of the device as a result of the corrosive forces within the environment of the living body. Once microcracks begin device failure is inevitable. Different formulations of polyurethane are somewhat resistant to this enzymatic degradation process [8]. Chronoflex which is a carboxylated aliphatic nonether based polyurethane is resistant to this process and therefore very biostable [9]. Tecoflex, on the other hand, is an aliphatic ether based polyurethane which is known to develop microcracks when implanted for long periods.

Silicone rubber is produced from polydimethylsiloxane (PDMS). PDMS is blended with vinylmethylsiloxane and silica to produce medical grade silicone. This material is extremely biostable, compliant and kink resistant but mechanically weak. This mechanical weakness can be overcome by increasing the silicone products' thickness. Thus, catheters composed of this material will have thicker walls and a smaller internal to external diameter ratio.

For subcutaneously implanted devices a reservoir is required. These reservoirs have been constructed from stainless steel, titanium, and plastic. Stainless steel is a non-reactive biostable metal which has many biomedical applications. This material is strong, durable, and inexpensive. Its disadvantages are that it is heavy, radiopaque, and ferromagnetic. Its weight can result in device descent and catheter pullback. Its ferromagnetic properties can result in MRI artifacts, which can prevent the use of this diagnostic modality. Its increased radiopacity can also prevent visualization of lesions that are adjacent to the device. Titanium is a non ferromagnetic, biostable, light metal with great strength. This material

has been used in the construction of many subcutaneously implanted devices. Its metallic properties are far superior to that of stainless steel, however, it is expensive and heavy as compared to non-metallic man-made materials. Plastic has been used in the construction of many biomedical devices. It is inexpensive, lightweight, non-ferromagnetic and non-radiopaque. Unfortunately, plastics are not as hard as metallic materials. This is potentially important in devices that are being accessed with metal needles. The needles can gouge the plastic and potentially cause premature device failure. Another problem associated with the use of plastics, is material availability. Many manufacturers are unwilling to accept the liability associated with the biomedical use of their product. They have therefore restricted sale of man-made materials and will only sell it to non-biomedical manufacturers. Composite construction uses both metal and plastic in a single device. This combines the positive features of each of the two materials. Many devices are currently being constructed in this fashion.

Devices:

Various types of central venous access devices are available to satisfy the particular clinical needs of the patient. These devices can be categorized into one of two large groups: peripherally inserted central venous access devices or centrally inserted central venous access devices. Peripherally inserted venous access devices include PICC lines as well as peripherally inserted subcutaneous reservoirs. The PICC line can be, and is often, placed at the bedside by specially trained personnel [10]. In patients with a paucity of obvious peripheral veins, image guidance is often required for placement of these lines [11]. Peripherally implanted subcutaneous reservoirs are small single lumen devices which are implanted within the subcutaneous tissues of the forearm or arm and connected to a small diameter peripherally inserted venous catheter [12]. The tip of this catheter is positioned in the SVC. These devices are suitable for long-term therapy and often can remain in place for several years.

Centrally inserted central venous catheters can be subdivided into two groups: high flow catheters and infusion catheters. High flow catheters are designed to support blood flow rates as high as 400 ml per minute. These high flow rates are required for specific uses such as dialysis or plasmapheresis. For short-term use, non-tunneled, rigid catheters are often utilized. In the chronic setting, large diameter, tunneled, soft catheters constructed of polyurethane or silicone are preferred [13, 14].

Centrally placed infusion catheters can be used in both the acute and chronic setting. These devices are utilized for the administration of various pharmacologic agents and blood sampling. Non-tunneled catheters (e.g. triple lumen catheters), which are inserted at the bedside, are suitable for short-term use. These devices have a high infection rate and require daily maintenance, which limits their use to the hospitalized patient.

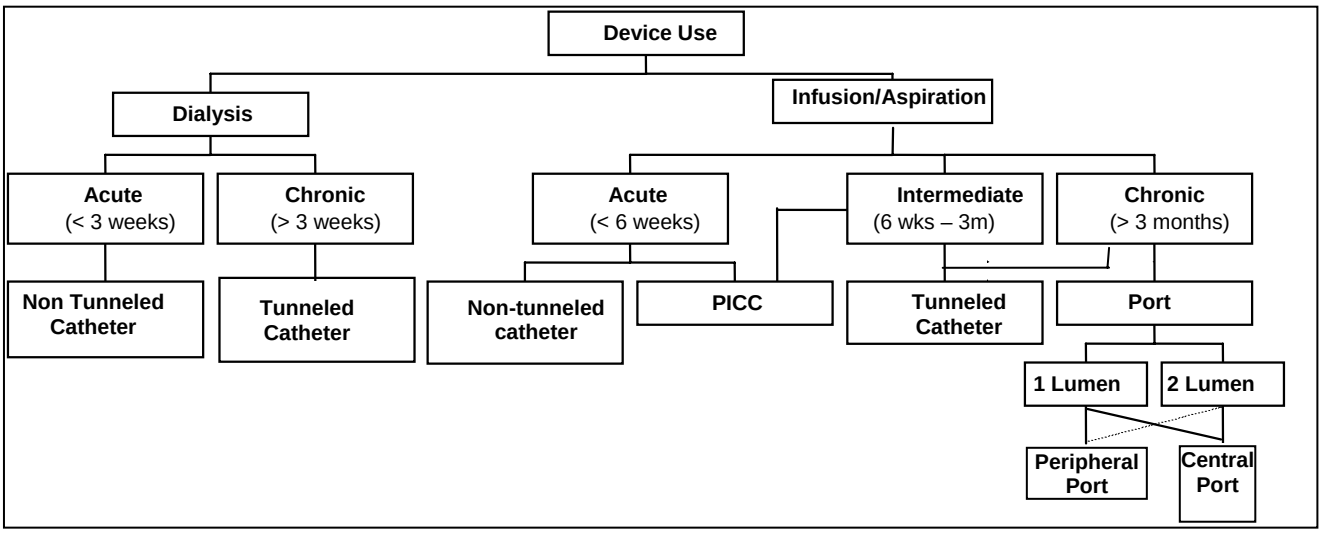
Tunneled catheters traverse a subcutaneous tunnel prior to entering the central vein. They also possess a Dacron cuff, which surrounds the catheter and is positioned within the subcutaneous tunnel. This Dacron cuff permits tissue ingrowth and reduces the risk of infection and dislodgement. These catheters are available in a variety of sizes and can be single, double, or triple lumen. These catheters have a variable life span. They often can remain in place, complication free, for several months or even years [15]. The major disadvantage of this type of device is that it has an externalized portion, which limits patient's activities and requires daily maintenance. For these reasons, tunneled catheters are often utilized for patients requiring circulatory access from six weeks to three months.

In the patient who will require intermittent circulatory access over the course of several months to years, centrally inserted subcutaneous venous access devices (SVADs, or "ports") are ideal. Similar to the peripherally implanted access devices, these devices cannot be dislodged, do not limit patient activity, and have a reduced infection rate as compared to externalized catheters [6]. However, centrally inserted SVADs have several advantages over their peripheral cousins. These devices have larger access septums, can be attached to larger diameter catheters, and are available in single and double lumen varieties. The larger septum surface area eases device access and reduces the chance of inadvertent administration of pharmacologic agents within the subcutaneous tissues. The larger diameter catheters permit more reliable blood draws and the availability of double lumen devices permits administration of complex multi- agent chemotherapeutic regimens.

A traditional limitation of PICCs and ports is flow rate. With the emergence of techniques using high injection rates for CT, such as CT angiography, there is a need for higher flow devices in patients with low flow venous access devices. There are now a number of PICCs which are designed to accommodate power injectors for CT. Typically, these can accommodate flows up to 5 ml/sec. At the time of this writing (1/2008) there is one manufacturer with an approved chest port for power injectors (Bard). The number of manufacturers offering these devices is likely to expand in the near future.
An earnest effort by device designers to improve function, ease implantation, and reduce complications has lead to the development of various unique access device designs. These unique designs, which are found in each of the different access device categories, are purported by their manufacturer to provide certain advantages over a competing product. Often these modifications do provide a real advantage where as on occasion, the advantage is only theoretical. It is therefore left up to the implanting health care professional to use a product with characteristics that match the patient's clinical needs.

Device Selection:

In selecting the appropriate access device several questions must be asked. What is the access device needed for? How long will it be needed? How many lumens are needed? How often will it be accessed? Are there any lifestyle considerations that might be important? Would a particular device design more appropriately match the patient's clinical needs? Answering these questions is key to choosing the appropriate device. Following is an algorithm that highlights some of these points.



Conclusions:

Rapidly advancing technology has lead to the production of many new and unique access devices. Each unique device may offer a particular feature that may best suit a patient's specific clinical need. There are many other unique circumstances which may push for a specific device. For example, a patient on antiplatelet therapy such as Plavix, in whom holding the drug is contraindicated, may be better treated with a non-tunneled catheter rather than a port, even if the port would otherwise seem the better choice. A patient receiving continuous infusion of a chemotherapeutic agent (e.g. 5 fluorouracil) may find a chest device more convenient than an arm one. Through familiarity with the wide variety of access devices combined with a clear understanding of the patient's access requirements is essential in choosing the most appropriate access device.

PERIPHERAL VENOUS ACCESS:
PICCs AND ARM PORTS

PICCs are peripherally inserted central catheters. PICCs were initially developed for the neonatal and pediatric populations to deliver hypertonic or sclerosing medications centrally, but their use has expanded to adults, particularly with the increased use of outpatient intravenous therapies. PICCs have replaced tunneled chest wall lines for intravenous access for antibiotics, chemotherapy, hyperalimentation, or administration of blood products. We are experiencing an increasing number of requests for PICC placement in hospitalized patients with poor venous access, in many cases replacing temporary central line placements in these patients. Indeed, the use of PICCs is one of the highest growth areas in vascular access. An important recent development is the introduction of high flow PICCs, ones capable of injecting contrast at up to 5 ml/s. the increasing use of CT angiography makes these devices essential in the care of the hospitalized patient.

PICCs are best suited for those patients requiring frequent or continuous administrations of medications, rather than those with intermittent needs (less frequently than every day or every other day) who would be better suited for port placement. In most patients, continuous or daily access of a port defeats the purpose of this device and increases the infection rate.

Why choose a PICC over a Hickman catheter? PICC insertion is quicker, easier, and has fewer associated risks. The catheter is cheaper. The average time of the procedural portion, excluding prepping and suturing, is less than 10 minutes in 95% of patients. In many patients only local anesthesia is required, though we offer conscious sedation to those patients who are nervous or if access to the vein is not achieved quickly. There is no risk of pneumothorax or significant air embolism, and the puncture site is compressible. We prefer that patients have platelet counts greater than 50,000 and no coagulopathy, but exceptions are the norm. While it has not been proven, we believe that the risk of central venous stenosis or thrombosis is lower with these small caliber peripheral devices as opposed to the larger tunneled catheters. Also, some papers have suggested that a central venous stenosis is caused by the site of venous puncture, so catheter placement through an arm vein would be less likely to effect the central veins. The infection rate appears to be lower for PICCs than tunneled catheters in our experience. This is supported by research done by Maki, a prolific infectious disease specialist at University of Wisconsin[40]. He noted that insertion site bacterial colonization rates were almost 100 times greater with central venous catheters than with peripheral sites, adding that colonization of the insertion site is the single most powerful predictor of increased risk for catheter related infection. Rates of local catheter infections were 6.5 times greater with central catheters than peripheral accesses, and bacteremia rates were markedly increased with these central devices. Finally, many patients fell "less violated" by having what they view as a long, small caliber IV line through their arm rather than a tunneled catheter on their chest.

Several years ago, Joe Bonn, MD, of Thomas Jefferson University Hospital, performed a clinical comparison of 106 surgically placed, tunneled central venous catheters with 139 PICCs. The number of patients in the study was limited by a precipitous decrease in the number of tunneled chest wall catheters being placed at Jefferson. Surgically tunneled catheters were placed, on average, three days after catheter placement was requested whereas most PICCs were placed on the same day or next day after the request. No insertion complications were experienced with patients receiving PICCs, while four surgically-tunneled catheters were malpositioned, two could not be inserted, and one patient had significant bleeding complications. Complications such as dislodgment, fracture, and migration were somewhat more common with PICCs, but these problems often required readmission for patients with tunneled catheters unlike those with PICCs who were expeditiously treated as outpatients. Catheter occlusion was seen in 9 PICCs as compared with one of the larger surgically tunneled catheters. However, thrombophlebitis was seen in six of the tunneled catheters and none of the PICCs in this series.

The infection rate was 1.87/1000 catheter days for patients with tunneled catheters as compared with 0.68/1000 catheter days for PICCs. In summary, PICCs were inserted more promptly, had fewer insertion complications and requirements for follow-up studies, and had lower risks of thrombophlebitis and infection. PICCs were more likely to occlude or dislodge, but were easier to manage without readmission.

PICCs were designed for bedside placement through an antecubital or forearm vein without fluoroscopic guidance. Initially, interventional radiologists were involved with PICCs for correction of malpositions

during blind insertions, to negotiate across stenoses and occlusions, and to gain access in those patients with depleted forearm veins which is becoming more common in hospitalized patients with frequent access needs. While mechanical fatigue is less concerning with the newer PICC products, we believe that upper arm placement is preferable over the forearm or antecubital space for both cosmetic reasons and because the PICC is less obtrusive to daily activities. Also, the device is less prone to kinking or migration when not placed across the elbow joint.

Placement of PICCs by the interventional radiology service offers the ability to place the catheters in patients with non-palpable forearm veins and to ensure appropriate catheter tip positioning. Experience with catheter and guidewire techniques certainly facilitates placements, particularly with some of the products which are available because they are better suited for placement using the Seldinger technique. Furthermore, when compared to surgical placement of tunneled chest wall catheters, PICC placement in radiology offers the advantage of being cheaper and much more accessible since the associated costs of the operating room, recovery room, and anesthesia are avoided. Likewise, since we control our own room schedules and want to accommodate the referring physicians, we provide same day or at worst next day service for venous access. We have tried to avoid doing venous access procedures on the weekends. However, we do receive occasional requests for assistance which includes inpatients with poor access, patients going home over the weekend who, for some reason, we weren't contacted about on Friday, and for patients undergoing emergency chemotherapy who are usually leukemia patients. John Cardella reported on the experience in Hershey comparing PICC placement by physicians on the patient floor with placement in interventional radiology. Both groups had about 150 patients. There was a 69% success rate of PICC placement into the superior vena cava from blind insertion. In 74% of cases, venous access was achieved but the catheter tips were positioned improperly in this 5% group. Interventional radiologists (including radiology residents) were able to successfully place 99% of the PICCs. In two cases early in their experience, they were unable to thread the PICC centrally, but a 4 Fr angiographic catheter was correctly positioned.

Several series of blind PICC insertions by nurses have noted success rates in the 60-80% range. Because of the high success of PICC placement by John Cardella and his group, they began placing all of the PICCs in that hospital for almost two years. To save costs, the hospital hired four nurses for bedside PICC placements. In a subsequent study from Hershey, they noted that bedside placement by four specially trained PICC nurses were technically successful in 327 (82.6%) cases. Of the 69 patients in whom nurses could not place the PICCs, 45% were due to an inability to cannulate a vein, 38% were an inability to thread the catheter, and 17% were malpositioning of the catheter; these patients were referred to interventional radiology. PICC placement was not attempted by the nurses in another 63 patients, and these patients were also referred to interventional radiology. The hospital determined that in any inpatient in whom more than nine days of intravenous access was anticipated, bedside PICC placement by a nurse would be more cost-effective than multiple placement of peripheral intravenous lines. More recently, there have been a number of reports by burses using ultrasound guidance, with high success and low complication rates.

Techniques for PICC and arm port placement have been well described in the literature[38]. There have been only a few modifications in technique since 1993.

PICCs are available from a large number of manufacturers. Kits designed for use in IR usually include some sort of micropuncture access kit, which includes a 21 gauge needle, platinum tipped 0.018 inch guidewire (steel or nitinol shaft), and a coaxial sheath/dilator tapered to the wire which allows direct placement of the catheter through the sheath without additional device exchanges. These access kits are also available independently (e.g. Cook Denny kit).

PICCs may be placed using blind access, ultrasound, or fluoroscopic guidance for access and placement. The advantages and disadvantages of each of these methods have been discussed elsewhere. In a recent comparison of ultrasound versus venographic insertion, Chrisman et al, concluded that the decision to use either method can be based on clinical grounds and/or physician preference[39]. There is an occasional patient who exceeds the weight limit of our angiographic tables. In these patients we place a PICC in our holding area using ultrasound guidance to access a vein. The PICC is inserted blindly by

approximating the distance to the cavoatrial junction using the paper ruler that comes with the kit, and then checking the catheter tip position using a portable chest radiograph.

We adhere to good sterile technique for PICC placement including a surgical scrub and wearing caps, masks, gowns, and goggles. We do not administer intravenous antibiotics prior to catheter placement A tourniquet is placed around the upper arm.

It is worth mentioning the choice of skin prep solution. Conventional skin prep in the US has been betadine solution for many years. Recently, FDA approved a chlorhexidine solution for use in the USA: Chlora-Prep One-Step is a combination of 2% chlorhexidine gluconate and 70% isopropyl alcohol delivered with a single-use applicator. CDC guidelines recommend chlorhexidine solution preferentially. Chlora-prep is best used on intact skin. For open wounds or excoriated skin, the alcohol in the prep may be quite irritating to the patient.
We place PICCs in the non-dominant arm, in the event that thrombophlebitis may develop. However, it may be preferable in a disoriented patient to place the PICC in the dominant arm in attempts to reduce the patient's ability to pull out the catheter. The site should be sufficiently above the elbow so that the PICC hub will stay above the elbow joint. Choose a site in the grove adjacent to the biceps muscles, and palpate the location of the brachial artery. We strongly favor routine real-time ultrasound guidance. The cephalic vein is an excellent choice when it is of sufficient size for access.

Limit local anesthesia to skin and subcutaneous tissue, as deeper infiltration around the vein may cause venospasm. A superficial skin knick is made, and the soft tissues spread.

After gaining access by achieving free return of blood, gently advance the 0.018 inch wire, which often requires twiddling. The platinum tip of this wire is much more gentle than the standard Cope mandril wire which is prone to induce spasm. Apply gentle skin retraction and back tension while passing the peel-away sheath. If difficulty is encountered, pass the inner dilator portion first. If the peel-away becomes damaged during the initial attempt at placement, just cut a beveled tip on the end.

Advance the .018 wire to the cavoatrial junction to determine the necessary length of the catheter, and mark or bend the wire at the hub of the peel-away. Flush the inner dilator of the peel-away sheath.

The mark on the wire should be placed 1-1.5 cm behind the wings of the PICC for the appropriate length. Next, advance the PICC through the peel-away sheath with the hydrophilic obturator in place. Most of the time the PICC will naturally be directed into the superior vena cava.

If not, use the obturator (with or without placing a gentle curve on the tip) as a torquable wire, or try advancing the PICC off of the obturator. If this doesn't work, use a .018 or .025 Glidewire. Ideally, the catheter tip should be positioned at the cavoatrial junction because the increased blood flow and cardiac motion diminishes fibrin sheath formation at this level. Remove the peel-away before taking out the hydrophilic obturator to prevent catheter kinking at the skin.

The PICC should be advanced such that this transition zone between the catheter and hub is completely inserted through the skin to prevent kinking of the thinner portion of the catheter and to allow more secure suture placement at the skin entry site. Apply compression at the puncture site for a few minutes if there is any bleeding. Fluoro the length of the catheter again to ensure that the tip position is appropriate, and that there are no kinks, especially at the skin entry site. Suture the PICC to the skin.

Finally, place a sterile clear or gauze dressing. If the hub of the PICC dangles in the antecubital fossa, just tape it out of the way. The PICC should be flushed per manufacturer recommendation or hospital protocol. Most PICCs need heparin flush daily. Valved PICCs, e.g. Groshong catheters, need no heparin.

Complications during PICC placement are uncommon. We usually have one patient/yr in whom a PICC cannot be successfully placed, and this is usually due to venospasm. This is usually induced by needle punctures or attempts at advancing the guidewire. We recommend using a single wall puncture technique. Venospasm is more common with larger needles which accompany some of the PICC kits,

ranging from 14-18 gauge. These needles are satisfactory for access of antecubital veins, but inappropriate for upper arm veins. The Cook kit has a 21 gauge needle. If placing another device, use a micropuncture kit for initial access. Also, it's important to use a gentle guidewire and twiddle the wire while exiting the needle. Make sure there is brisk, free flow of blood from the needle before initial wire placement. Injection of lidocaine too deeply and contrast extravasation from errant punctures can also induce or exacerbate spasm. Use the tourniquet to distend upper arm veins, and nitroglycerin may be injected through a peripheral intravenous line in aliquots of 100 mcg to help relieve spasm. A few minutes of patience is often most helpful. Rarely, a patient may experience numbness, tingling, or shooting pains down the arm during placement of the needle or peel-away sheath. This indicates potential injury to the nerve; select another puncture site! Current ultrasound units are able to see the nerve in relation to the veins in may cases. This is usually a problem only when trying to use one of the brachial veins, paralleling the brachial artery.

Central vein occlusion is another potential problem. Occasionally, a Glidewire may be negotiated through the collaterals with catheter tip placement at the cavoatrial junction. This is not always easy, particularly with silicone catheters. Several companies make polyurethane PICCs which offer improved trackability over a guide wire. In cases where the central veins are occluded bilaterally, the PICC tip may be placed peripherally if the infusate is not too sclerosing if attempts at crossing the occlusion with a catheter and guide wire are unsuccessful.

While insertion complications with PICCs are minimal, a number of complications during use have been reported in these two large series [IV Nursing 1993; 16:92-99, and JVIR 1996; 7:5-13]. Few present any real danger to patients and, as you can see, are mainly mechanical problems related to the devices. The most common complication at Hershey was premature or inadvertent catheter removal, although it is worth noting that they did not sew their PICCs in place. Thrombophlebitis and infection rate are other issues as with all venous access devices.

Catheter occlusion is a common complication, which is seen sometime during the life of the PICC in 5-10 %. In most cases this is easily treated at bedside with a brisk saline flush or low dose thrombolytic treatment (e.g. tPA 1 mg). If these are unsuccessful, try clearing the occlusion by passing a Glidewire through the PICC under fluoro. If thrombosis of the surrounding vein develops, try treating with heparin and symptomatic therapies. In patients with limited venous access options, try to keep the catheter in as long as tolerated. PICC tips can easily migrate with a brisk flush, but usually return to the original location. Tip repositioning is rarely required and can often be accomplished by a brisk saline flush during inspiration. Otherwise try to reposition by just passing a Glidewire through the catheter, or just change the catheter. Occasional inadvertent catheter removal is unavoidable, but suture the PICC to the skin with an added suture placed back around the wings for security in addition to the sutures through the wings. We have not encountered infections from the sutures. Catheter disruption or fracture usually requires a PICC exchange, as few PICCs have repair kits (a notable exception is the Groshong PICC). Damage is often caused by flushing with a small syringe which generates a greater pressure than the catheter can withstand. Don't use a 1 cc syringe, and be careful during injections with a 3 cc syringe. As long as there are no signs of local infection, we will exchange the PICC and maintain this same site. We've encountered problems with fractures of the double lumen PICCs due to incomplete reinforcement of the hub. Despite having a reinforced segment which says "clamp here," multiple clamping on the thinner part have resulted in PICC fracture.

If a PICC is removed for sepsis, treat the patient through a temporary access before placing another PICC. The need for intravenous antibiotics is our most common indication for PICC placement. Even though patients may have fevers, we will place PICCs as long as there are no signs of sepsis. If the patient has previously had positive blood cultures, we require a blood culture without growth for two days or that the patient has been afebrile for a day while receiving appropriate treatment before placing a PICC.

Ports:

Venous arm ports are smaller single lumen versions of products that have been available for placement on the chest wall. There are several new arm ports recently available from a number of manufacturers (e.g. Sims, Cook, Bard, Boston Scientific).

It's useful to have a few surgical instruments such as forceps and mosquitoes since this procedure is more involved. Port placement requires strict adherence to sterile technique, though we do not give antibiotics prior to placement of these devices. After vein access, the incision is extended, and a small subcutaneous pocket is created using blunt dissection. This needs to be about as big as the distal 1/3 of the pinky finger. The overlying skin should be thin enough that a finger in the pocket or diaphragm of the port can be easily palpated, but not so thin that the port will erode through the skin. Irrigate copiously and make sure hemostasis is obtained. Check to make sure that the port fits in the pocket. Securely attach the port to the infusion catheter, check for flow and leaks, place the port in the pocket, then close the incision. While ports commonly have suture holes provided, it has become common not to suture the port in position unless there is a specific need because of loose tissues. Closure is commonly in 2 layers, a deep layer of resorbable suture to close the potential space and provide mechanical strength, then a running subcuticular suture of 4-0 coated vicryl. See below for additional notes on incision closure. The port should be positioned in the pocket such that the suture line is not over the diaphragm. Place steri-strips, and access with a 1/2 inch non-coring needle if the port is going to be used immediately. Ports should be flushed at least once a month with heparinized saline if not in use.

Port removal consists of cutdown though the placement scar, freeing the catheter and removing it from the vein, then removing the port using sharp and blunt dissection. Local anesthesia is complicated by the presence of the scar, which delays time of onset of effective anesthesia; leave extra time for lidocaine to take full effect. The scar capsule around the port usually requires sharp dissection with a scalpel; we usually use a #15. Removing the catheter first allows the operator to use it to apply traction to the port during the removal. Closure is typically single layer using resorbable subcuticular technique with Vicryl 4-0. Steri-strips are applied to the incision margins.

Implantation of Tunneled and
Subcutaneous Chest Wall Access Devices

It is estimated that approximately 1.5 million chronic venous access catheters are implanted in the United States each year. This number is increasing at approximately 8% per year. Unfortunately, access related complications are quite common. Acute and late complications can cause significant morbidity and on occasion mortality. The cost of managing these complications is enormous. Good image guidance as well as proper implantation technique can prevent many of these complications and reduce their associated morbidity and health care costs.

The involvement of the interventional radiologist in the implantation of access devices has grown rapidly over the pass decade. Currently, a majority of the peripheral devices are implanted by interventional radiologists. This however is not the case with centrally implanted devices, which in a majority of the institutions, are implanted by the surgical staff. For the purpose of this review, we will focus on the implantation of centrally inserted central venous access devices, discuss insertion techniques, and highlight the merits of radiologically guided placement.

Technique
Preferred Access Sites:

Several central veins are available for insertion of access catheters. The subclavian veins, because of their location on the chest wall and the broad familiarity with subclavian access techniques, are the most frequently utilized veins. Access into these veins, however, is associated with significant long and short term complications [16]. Pneumothorax and symptomatic central venous thrombosis with resultant arm swelling are more likely to occur with subclavian vein access. In our view, jugular vein access is the preferred access site. This matches K/DOQI recommendations as well. This access, in the short term,

avoids pneumothorax and in the long term reduces the rate of symptomatic central vein thrombosis. Access of the internal jugular veins for the implantation of chronic central venous access devices has been avoided because of the torturous course the catheter must take as it comes across the neck down to the chest wall. The use of the low posterior approach to the right internal jugular vein is an alternative to solve this particular problem. The posterior approach involves accessing the internal jugular vein posterior to the posterior belly of the sternocleidomastoid muscle just above the level of the clavicle. From this location, the needle is directed from lateral to medial across the neck parallel to the operating table. When the vein is accessed in this fashion the catheter can assume a gentle curve as it courses through its subcutaneous tunnel. Routine use of real-time ultrasound guidance contributes to higher success and lower complication rates for central venous access.

Recently, there have been reports of a single puncture/incision technique for accessing the internal jugular vein from an infraclavicular approach. This technique avoids the need for separate creation of a tunnel for long-term catheters. First reported by Glenn[41], the technique uses a curved small gauge access needle such as the #22 needle found in normal micropuncture kits. Ultrasound is necessary, as it is used to follow the curved needle as it is advanced subcutaneously from the infraclavicular skin access to the lateral margin of the jugular vein at the base of the neck. Glenn[41] and Contractor[42] have reported using this technique for placement of tunneled central catheters, ports, and dialysis catheters, from both right and left sides.

In patients with occluded internal jugular and subclavian veins alternate approaches are necessary. Placement of a chronic catheter in the common femoral vein is an option, however, this approach is associated with a high incidence of symptomatic lower extremity DVT and an increased infection rate. With good radiologic guidance access into the inferior vena cava can be obtained through a translumbar or transhepatic approach providing an alternate route for chronic circulatory access [17, 18]

Guidance Modalities:

Ultrasound can be used to assess venous patency as well as direct the needle into a vein without injuring surrounding structures [19, 20]. High frequency transducers, 7 megahertz or higher, are preferred for visualizing superficial vascular structures. The use of a scored needle tip can enhance ultrasound visualization facilitating access of the vein.

Contrast material can also be used to guide venous access. Iodinated contrast as well as Co_2 gas injected through a peripherally inserted IV permits radiographic visualization of the subclavian vein [21, 22]. Once opacified, a needle can be directed into the subclavian vein under direct fluoroscopic vision.

Venous Entry

Once visualized, the internal jugular vein (or other) is accessed with a 21 gauge needle (e.g. “microstick”). The use of a small gauge needle reduces the trauma associated with inadvertent puncture of surrounding structures. Once entry into the vein has been gained, an 0.018 inch guide wire is advanced. The wire is advanced down to the level of the right atrium to ensure that entry into the venous system has been accomplished. Once the guidewire is in place, a 3 French/ 5 French coaxial dilator is inserted. Through this 5 French dilator a stiffer guidewire can be inserted permitting single step insertion of the large diameter peel away sheaths through which the access catheters are advanced.

Tunneled Catheters

Once venous access is obtained, an appropriate site on the infra-clavicular chest wall is chosen for the catheter exit site. After adequate local anesthesia a small incision is made at that location and a tunneling device is used to create a subcutaneous tunnel to the venous entry site. Prior to tunneling the catheter it is important to determine the precise length of catheter required so that the Dacron cuff can be positioned 1 to 3 cms from the catheter exit site and the catheter tip can be positioned at the RA/SVC junction. It is helpful to take a guidewire and position its tip at the RA/SVC junction and then make a bend or otherwise mark the back end of the wire where the catheter exit site should be. This wire is then

removed and is used as a template to cut the catheter to the appropriate length. Once cut to length, the catheter is attached to the tunneling device and pulled through the subcutaneous tunnel. After tunneling the catheter, attention is diverted to the guide wire in the central vein. Over this stiff guidewire the appropriate size peel away sheath is inserted. The dilator and guidewire are removed and the soft access catheter is advance through the peel away sheath and positioned in the SVC. Once the catheter tip is at the appropriate location, the sheath is peeled back and removed. Two important points must be made about this step. First, excessive advancement of the peel-away sheath into the vein should be avoided as this can often result in a kink in the sheath when the dilator and guidewire are removed prohibiting passage of the soft access catheter. Second, when the dilator of the peel away sheath is removed, great care should be taken to avoid air embolization. This can be accomplished by pinching the sheath closed, instructing the patient not to inhale, and rapidly inserting the access catheter into the sheath. For large bore Hemodialysis catheters, sheaths with hemostatic valves are now available. These considerably simplify the procedure.

Subcutaneously Implanted Chest Wall Venous access Devices (SVADs or ports)

The implantation of subcutaneous chest wall infusion devices is similar to that for tunneled catheters, however, a subcutaneous pocket must be created. A site over the anterior medial aspect of the second rib is chosen for reservoir placement. High medial placement is essential to avoid the descent of the device into the breast tissue and retraction of the venous catheter. The site is infiltrated with 1% lidocaine and an incision large enough to accommodate the access reservoir is made. Blunt dissection is used to fashion a subcutaneous pocket just large enough to accommodate the infusion device. Overlying subcutaneous fat thickness should be a minimum of 0.5 centimeters to prevent skin necrosis and a maximum of 1 cm to ease the transcutaneous access of the device. The pocket is irrigated with saline to remove tissue debris and hemostasis is achieved. The rear of the previously placed access catheter is cut to length and connected to the infusion reservoir. The reservoir is then inserted into the pocket and the pocket is closed in two layers: the subcutaneous layer with interrupted 3-0 or 4-0 resorbable sutures (e.g. Vicryl, Monopril) and the dermal layer with a running or interrupted 4-0 resorbable subcuticular stitch. Removal is identical to the process for arm ports, described above.

Some operators are using skin adhesive, 2-octyl cyanoacrylate (Dermabond, Johnson and Johnson) to assist in skin closure. While there is little data for this specific application, there is ample reported experience with this agent in surgical skin closure for other procedures. In addition to potentially speeding the time of closure, this agent can be used without a dressing, and patients can shower in 24 hours.

Complications

The incidence of complications is largely dependent on the type of device implanted [14]. Complications from most common to least include infection, catheter malfunction, venous thrombosis, pneumothorax, wound complications, and catheter fragmentation. In a review of our first 154 chest wall SVADs insertions, we noted certain advantages over classical surgical implantation. These included a high success rate, a reduced complication rate, a reduced request to implantation time, improved complication management, and reduced overall charges. In our series, technical success was 100% compared to the 5-8% failure rate among surgically implanted devices. In addition to our high success rate, our complication rate was lower then that reported in most surgical series (Table 1). Although these devices were all implanted outside of an operative setting, no acute local infections were noted within the first 30 days after implantation. When a complication did occur usually some form of intervention was required. In our series 65% of the complications required interventions outside of just device removal. These interventions included placement of small chest tubes, fibrin sheath disruption, catheter repositioning, and venous recanalization with thrombolytic therapy and intravascular stent placement. Many, if not all of these interventions, required extensive radiologic imaging which could not be performed by the surgical service.

Conclusions

Proper implantation technique can dramatically influence the incidence of both acute and late access complications. The use of good image guidance and thorough understanding of catheter and guidewire techniques can improve the overall success rate, reduce the complication rate, and permit treatment of complex access problems. By accomplishing this, costs related to circulatory access can be significantly reduced.

CENTRAL VENOUS CATHETERS FOR HEMODIALYSIS

Hemodialysis central venous catheters (CVCs) are large caliber lines designed to permit venovenous hemodialysis. These may be temporary, which should be used for less than 3 weeks, or long-term, tunneled hemodialysis catheters (THCs) which are intended for longer periods. The temporary CVCs are typically made from polyurethane and directly enter the vein, while THCs are made from softer polyurethanes or silicone. These have a subcutaneous course prior to entering the vein with a polyester cuff in this region to promote fibrosis – this helps secure the catheter and acts as a barrier to infection migrating intravascularly. Current catheters typically have two lumens, one for outflow to the hemodialysis machine and the other for return, although at least one THC system achieves this by way of two separate catheters. The large size of these catheters is due to the need for high flow rates to meet the requirements of relatively short dialysis sessions. Desired flows are typically at least 250 to 300 ml/minute, and preferably faster. Catheter sizes are typically 13.5 to 15.5 F.

The choice of device and the route of access are addressed in the K/DOQI standards (http://www.kidney.org/professionals/KDOQI/).

Patient preparation involves obtaining preliminary clinical and laboratory data (primarily coagulation parameters and platelets). After obtaining informed consent, a very limited ultrasound examination of the proposed access vein(s) can be done to assess patency. Given the known risk of developing post catheterization stenoses in the subclavian veins, these should be avoided so as not to interfere with the outflow from a potential hemodialysis arteriovenous shunt in the arm. Additionally, right-sided veins appear to be less prone to central vein occlusive problems than left ones. Therefore, the optimal access is the right internal jugular vein (IJV). If this is obliterated, the left IJV is the next choice. If the external jugular veins are open, it may be preferable to use. The access site is then sterilely prepped. For temporary catheters, three povidone-iodine washes can be used. When placing a THC, a more vigorous scrub is needed, typically two chlorhexidine scrubs followed by 3 povidone-iodine washes, with the field to include the upper chest, where the catheter will exit. Additionally, the operator needs to scrub his/her hands, all personnel in the room should be capped and masked, and the room should receive frequent, thorough cleansing if it is being used for placing tunneled lines. The procedure room should adhere to hospital operating room standards.

We prefer to puncture the right IJV using a 21 gauge needle and a low posterior approach, using ultrasound guidance. This transversely oriented venipuncture means that a temporary catheter will lie over the shoulder rather than under the chin and permits a gentler curve to the infraclavicular region for tunneled catheters. Large veins can usually be easily entered using surface anatomic landmarks for guidance, but ultrasound guidance should be available. A small footprint 7.5 MHz probe is optimal for this. Once the vein is entered, a 0.018 inch mandril wire is advanced under fluoroscopic guidance into the right atrium, or even the inferior vena cava, to confirm proper venous positioning, and the needle exchanged for a dilator.

The lengths given for double lumen temporary catheters are the distances from the tip to the region where the two lumens split apart. Two lengths are given for tunneled hemodialysis catheters: from the tip to the polyester cuff and from the tip to the hub. Given their stiffer nature, temporary catheters should have their tips at the superior vena cava-right atrial junction or high right atrium. Softer THCs should have their tips in the mid right atrium, to take advantage of the maximal blood flow available here and to limit

the potential of developing stenoses of the superior vena cava related to chronic catheter tip irritation. Consideration should be given to the possibility of catheter pullback from the initial placement in a supine patient, especially in those with large amounts of chest tissue. It may be advisable to position the catheter in the lower right atrium in such patients, anticipating that it will retract to the mid right atrium. Soft catheters have not been known to cause right atrial perforation. The proper catheter length to use in a patient can be determined by using a bent wire. While the wire should be bent at the venipuncture site for temporary catheters (taking into account the length of the hub of the dilator), it should be bent at the expected location of the cuff along the subcutaneous route for THCs.

Placing a temporary CVC is a simple matter of exchanging the dilator for the catheter and suturing it in place. Placing a THC involves first tunneling from an infraclavicular entry site to the venipunture site, after which, the dilator is exchanged for a peel-away sheath. The THC is then advanced through this, taking care to avoid air from entering the system or excessive blood loss from these large caliber conduits. Recently, large sheaths with hemostatic valves have become available; these are specifically designed for Hemodialysis catheter placement, and minimize the risks of serious back bleeding and air embolism. An additional technical aid is the use of a glidewire within the catheter, which may serve to stiffen it and allow easer advancement into the vein. After confirming brisk aspiration of blood from each lumen, they are primed with appropriate volumes of heparinized saline. We use 1000 units/ml heparin for THCs. The THC is secured at its entry/exit site with a 2-0 nylon stitch, taking care not to significantly constrict the lumen of these soft catheters, the venipuncture incision closed with a 4-0 absorbable stitch, and sterile dressing is applied. The retention stitch may be removed after the subcutaneous Dacron cuff s securely embedded in the track, usually 3 weeks or more. A post-procedure chest X-ray is obtained to assess for proper catheter positioning and pneumothorax.

A variety of problems are possible with hemodialysis CVCs. Procedure-related ones include pneumothorax, internal or transcatheter hemorrhage, and air emboli. The incidence of these events can be kept to nearly zero by using a low posterior approach to the IJV, a 21 gauge needle for the puncture, ultrasound guidance as needed for the venipuncture, fluoroscopic guidance for wire and catheter manipulations, introducing a THC into the peel-away sheath during a Valsalva maneuver or end-inspiration, and making sure that the clamps on the lumens are closed.

Catheter infection results in the failure of 11% to 28% of THCs. These may be local infections, involving the exit site or subcutaneous tunnel, or intravascular catheter infection, with septicemia. While most of these occur late, and are therefore related to contamination during dressing changes, dialysis, or hematogenous seeding from another source, a smaller number result from contamination at the time of placement. By convention, any infection occurring within 30 days of catheter placement is considered a procedural complication. Antibiotics may control infection without catheter removal. If this is unsuccessful, one can try exchanging a catheter over a wire for non-purulent processes. If pus is present, exchanging the catheter with creation of a new tunnel may suffice, but persistent or life-threatening infections should be treated with removal of the catheter and placement of a temporary one through a new route. Some centers believe that trying to maintain a catheter with infections from certain organisms, such as Staphylococcal aureus, runs the risk of potentially devastating recurrences, such as epidural abscess, and therefore recommend removing such infected catheters immediately.

Prevention of infection is best accomplished by proper attention to sterile technique during catheter placement and during subsequent care. Dressing changes should be performed at least three times per week. The value of using a prophylactic antibiotic, such as vancomycin, at the time of catheter placement is unclear, as is the use of topical antibiotics or a povidone-iodine solution. We use the latter but not the former. Similarly, the issue of using transparent, semipermeable membranes as opposed to dry gauze dressings is unsettled. Some catheters have an additional silver-impregnated cuff of collagen that has antiseptic properties. Interestingly, some studies have shown lower rates of infection with IJV catheters than subclavian vein ones.

Antithrombotic hemodialysis catheters are now available from several manufacturers. These products have a heparin surface coating that resists the deposition of plasma proteins and platelets for an extended period of time. As demonstrated by in vitro studies this antithrombotic activity is reported to

persist for 30-90 days. However, there have been no prospective clinical trials that have yet demonstrated the clinical effectiveness of these surface coatings. At this point in time the value of these products is based upon our understanding of the biological processes the lead to catheter-related thrombosis and infection, and the ability of these surface coatings to resist these processes, but not upon any published clinical studies.

Catheter malfunction results in the failure of 17% to 53% of THCs. This consists of any mechanical problem interfering with its use, including external catheter dislodgment and perforation as well as the more usual issue of poor flow. When poor flow is encountered, dialysis centers will typically try to switch the inflow and outflow lines, or to fill each lumen with low dose tPA, 1 mg per lumen.

When empiric low dose thrombolytic therapy fails, patients are generally sent for radiological evaluation. Our routine first consists of visual inspection for external kinks, holes, an excessively constrictive stitch, or an exposed cuff. This is followed by fluoroscopic inspection for internal kinks and proper positioning of the tip, generally in the mid right atrium. Vigorous aspiration is then performed to confirm poor flow. The first 5 to 10 ml of fluid aspirated should be discarded as this contains the highly concentrated heparin used to prime the lumens. Contrast is then injected. If no mechanical problem is found, and if thrombolytic therapy fails, we recommend catheter exchange.

Over an 18 month period, we determined that the most common problems with malfunctioning THCs were malpositioning and pericatheter thrombus, followed by dislodgment and kinking. Malpositioning is managed by placing the new catheter in a proper position. Fibrin sheaths and small clots at the tips of catheters can be treated by disrupting it with a large angioplasty balloon (e.g. 10 to 14 mm diameter x 4 cm length), although immature ones can even be disrupted by simple manipulations with a curled heavy duty wire. More extensive pericatheter thrombus may require tPA infusions and patients who rapidly develop thrombus should probably be anticoagulated. We no longer use a transfemoral snare to strip fibrin sheaths. Even tunneled catheters can be exchanged easily over a guidewire, which is cheaper and faster than transfemoral catheter stripping.

THC malfunction appears to be less likely with IJV access as compared to the subclavian vein and with proper tip positioning in the right atrium.

Reported one year survival rates for long-term hemodialysis catheters range from 25% to 74%, although these do not include the results of radiological treatments. In the subgroup of patients with malfunctioning catheters, we were able to achieve a 1 year primary assisted patency of 50% using the above methods, although many patients had more than one treatment.

Alternative Central Vein Access

Translumbar IVC catheters

Since the initial report by Kenney [23] in 1985, there have been a series of reports on the success of percutaneous translumbar IVC catheter placement. This technique is recommended when routine access via the jugular or subclavian veins or SVC is unavailable. In children, catheters are 6 to 8 French. In adults, single and multilumen catheters ranging in size from 6 to 18 French can be used. Both external catheters and implantable ports may be placed using this approach. These catheter sizes support the full range of central venous device applications, including dialysis. Anticoagulation should be reversed and any coagulopathy corrected prior to device placement. Prophylactic antibiotics are given if that is the general protocol used for venous access device placement; a regimen providing coverage for *staphylococcus* such as cephazoline 1 gram IV is in common use. Conscious sedation and local anesthesia are given. General anesthesia is rarely needed.

Technique

The vein access site in adults is over the right iliac crest 8 to 10 cm (4 finger breadths) lateral to the midline. Since the skin entry site is in the back, the catheter is tunneled to a right flank exit position for better patient comfort and easier use. Prior to skin preparation, the proposed access and exit or port implantation sites are chosen. A large sterile field is established covering the right side of the back, right flank, and right anterior abdomen and chest. The patient is positioned in a prone oblique position with the right side sufficiently elevated to allow access to the planned exit site.

The three procedure steps are establishment of venous access, tunneling, and creation of the exit site or port pocket. The order is arbitrary but access is usually first. Percutaneous catheterization of the IVC using a translumbar approach is performed using C-arm fluoroscopy. Direct IVC catheterization is analogous to translumbar aortography. The IVC is generally more lateral than the aorta and is more oval in shape [24] . A preoperative CT scan confirms normal IVC anatomy and helps to plan the best position and angle for needle placement. Intra-operative sonographic guidance may help in pediatric cases. Placement of a guiding catheter from a femoral vein approach is used in the occasional case of difficult access but is not routinely necessary. A short 1 to 1.5 cm transverse incision is made at the access site. A 21-g needle is advanced at a cephalad oblique angle entering the IVC below the renal veins at the L2-L3 level. The needle may first be directed towards the anterior edge of the vertebral body, then redirected just anterior to this to enter the IVC. The deep tissues around the spine and IVC are often sensitive to pain; deep anesthetic can be given through the access needle. A palpable “pop” may be felt as the vein is entered. There should be free aspiration of blood through the needle. A very soft, platinum tipped 0.018 inch (0.46 mm) guidewire (e.g. Neff access kit, Cook Inc., Bloomington, IN or AccuStick, MediTech Inc., Natick, MA) is advanced through the needle and the coaxial dilator is then placed over the wire. After exchange for a heavy duty guidewire (e.g. Amplatz guidewire, Cook), the track is dilated and a peel-away sheath is placed with its tip in the IVC. The sheath chosen should be 1- or 2- French larger than the desired catheter.

The catheter exit site or port pocket may then be created. This is usually in the right flank or below the right breast but can be modified as needed. For ports, the pocket is made over the lower ribs so that there is a secure base for palpating and accessing the port. Special considerations apply for high flow catheters such as those used for hemodialysis. Because these catheters are shorter than those used for other purposes, a more lateral or posterolateral exit site may be used.

The tunnel is created between the sheath entry point and the exit or port site. Lidocaine 1% is given subcutaneously along the course of the tunnel. Any standard tunneling tool can be used. The tunnel is usually longer than that used for chest wall catheters, and in addition has to make a curved path around the flank. The Davol tunneler (Bard, Salt Lake City, UT) is a 12 inch semi-rigid nylon tunneler which can be used to pull a catheter from its nose or tail; it is very effective for the long, flank tunnel used in this procedure. In some cases it may be necessary to make an additional flank incision and create the tunnel in two parts because of the length of the tunnel and the curvature of the flank. This will also be necessary in patients who have had prior surgery, injury, or skin disease along the planned tunnel path. The catheter is pulled through the tunnel and trimmed to the desired length. It is introduced through the sheath and positioned at the cavoatrial junction; the sheath is then peeled away. Depending on the type of catheter used, the order and technique for tunneling and catheter length trimming may need to be adjusted. For example, valved catheters such as the Groshong (Bard) are placed in the vein prior to tunneling the back end to the exit site.

The catheter should be flushed immediately with heparin. The back incision is closed using a subcuticular suture or butterfly adhesive strip. For external catheters, an anchoring silk suture is tied around the catheter at the exit site. The anchor suture should be left in for 3 weeks while the subcutaneous Dacron cuff is fixed by in-growth of connective tissue.

Ports may be placed using this route. The port reservoir should be placed over the ribs to provide a stable platform for access.

One difficulty associated with the procedure is a tendency of the sheath to kink at the point of entry into the IVC. The chance of this happening can be decreased by making an oblique track to minimize the angle at the junction between the sheath and the IVC. If a kink prevents passage of the catheter, the operator can pass a guidewire that has a low coefficient of friction (e.g. Terumo Glidewire) through the catheter to stiffen it. The catheter and the wire can be advanced as a unit into and through the sheath. If this is still not successful, the guidewire may be advanced in front of the catheter through the kink; the sheath is then retracted so that it is just entering the IVC and is no longer bent, then the catheter and guidewire can be advanced together.

Potential procedure complications specific to this route include retroperitoneal hemorrhage, injury to the ureter, and puncture of an abdominal viscus such as the duodenum or colon. Despite the catheter size, bleeding at the site of IVC entry has not been a problem either at the time of placement or removal. Laceration of the ureter has not been reported; establishing an access track close to the spine should avoid the ureter. Viscus perforation has not been described.

Results

Denny reported successful use of the translumbar IVC route in seven procedures in six patients with 6- to 12-French catheters, with no case of subsequent catheter malposition or IVC thrombus [25]. Lund placed 46 catheters in 40 patients [17]. The catheters used were 37 single lumen 14.4 French apheresis catheters, seven dual lumen 12 French catheters, and two single lumen 9.6 French catheters. IVC thrombus occurred in eight patients, two of which were occlusive. All thrombi were successfully lysed with urokinase. Catheter malposition was found at follow-up in five patients: four catheters were repositioned angiographically, while one resumed its position spontaneously. The patient's position, respiratory motion, coughing, sneezing and vomiting all may cause the catheter to move. CT scans were performed in 31 patients at 1 to 10 weeks (mean 13 days) following the procedure and in 13 patients at 1 to 9 weeks (mean 19 days) following catheter removal. None showed retroperitoneal hemorrhage. In three patients, the catheter tip migrated out of the IVC. This was felt to be related to patient obesity and a short intravascular catheter length. An additional cause of catheter dislodgement in my personal experience has been premature removal of the external catheter anchor stitch. Two patients in whom the anchor stitch was removed at two weeks found the catheter in bed beside them the next morning.

Hemodialysis can be done using the translumbar route. A single case was reported by Gupta et al [26]. Lund reported placement of 17 catheters in 12 patients [27]. All placements were successful. Thrombotic complications occurred 7 times (0.33/100 patient days). Infectious complications occurred 6 times (0.28/100 patients days). Cumulative patency was 52% at 6 months and 17% at 12 months. These rates are comparable to those reported using hemodialysis catheters at other sites.

The use of the translumbar IVC technique in children has been reported by several authors. Denny reported a two year old child with short bowel syndrome in whom a single lumen 7 French Broviac catheter was placed [4]. Robertson et al reported three children [28]. Azizkhan et al subsequently reported excellent results in seven children using the translumbar approach for four catheters and the transhepatic approach for seven; all but one patient were younger than 2.5 years [29]. Recently, Malmgren et al reported 12 catheters placed in 4 children. All procedures were successful and uncomplicated. The median catheter patency was 4.8 months (range 1 to 10 months).

Transhepatic IVC catheters

Placement of a long-term central catheter using a transhepatic approach to the IVC was described in a case report by Crummy et al [30]. Only a small number of cases have been reported, although anecdotal reports suggest that its use is more common. Transhepatic IVC access is a good alternative when the translumbar approach is not feasible. Catheters and ports both large and small can be placed using this method. Indications for catheterization in the reported patients have mostly centered on parenteral nutrition. I am unaware of hemodialysis access being placed this way.

Technique

The approach is analogous to that of transhepatic cholangiography and biliary drainage. Access is from the right flank intercostal or anterior subcostal approach. Ultrasound and CT are used in procedure planning. Ultrasound is often used for intra-procedural guidance; ultrasound helps to avoid major intrahepatic vascular structures and large biliary radicles. Access to the IVC can be planned either through an hepatic vein or direct to the IVC. For the former, the middle hepatic vein is the largest and is the primary choice.

After choosing the access and exit or port sites, the skin is cleansed widely. The use of broad spectrum antibiotics as prophylaxis is suggested for this route although data are lacking. Local anesthesia is given subcutaneously using lidocaine 1% and is carried down to the liver capsule. A 21 gauge needle is advanced with fluoroscopy or ultrasound guidance. When blood is freely aspirated, a soft-tipped, platinum 0.018 inch (0.46 mm) guidewire is advanced. A coaxial dilator (e.g. Neff set, Cook or AccuStick, MediTech) is placed and a heavy duty guidewire (Amplatz guidewire, Cook) is advanced to the right atrium or the SVC. A peel-away sheath large enough to accommodate the desired catheter is then placed.

The exit site is then prepared. Ports should be placed over the ribs for a secure base of access. External catheters can be brought out where convenient. The catheter is passed between exit and access site in whichever direction is appropriate for the device being used. Similar to the translumbar route (see above), a lengthy, complex tunnel may be needed. The catheter is cut to length; due to the relatively short intravascular distance, the catheter tip is usually left in the right atrium. Excessive length in the atrium may lead to atrial arrhythmias and bothersome palpitations, or prolapse across the tricuspid valve with ventricular irritability. Care should be taken to leave a sufficient length of intravascular catheter to avoid inadvertent malposition during respiratory excursion of the liver. Some degree of slack at the entry point into the liver may be advisable. In the pediatric age group, patient growth may greatly shorten the intravascular portion. Hepatic vein rather than direct IVC access may be preferred in these patients so that intravascular length is maximized [31 11].

Results

Kaufman et al reported placement of a 9 French catheter for long-term total parenteral nutrition with five month followup in a patient with infrarenal IVC thrombus [32]. In the report by Azizkhan 11 transhepatic catheters were successfully placed in seven children [31 11]. Hepatic vein entry was chosen to maximize the intravascular length.

No procedure complications attributable to the transhepatic approach have been reported, although the number of reported cases is quite small. There are anecdotal reports of catheter tip dislodgment which are probably due to the excursion of the liver during respiration.

Access using Collateral Veins

Even in cases of extensive central vein occlusion, including the IVC, alternative routes of percutaneous catheterization often can be found. The modern angiography suite with state-of-the-art fluoroscopy, digital angiography, and imaging aids such as road mapping and last image hold assists in localization and puncture of small collateral veins. Intra-operative sonography provides added guidance in many cases. Collateral veins will often be hypertrophied from high venous flow secondary to central vein obstruction. Small vessel catheterization systems including 21 gauge needles, 0.018 in. (0.46 mm) platinum or gold tipped guidewires, and small sheaths are used for cannulation and passage of catheters through collateral networks to the central veins. Due to the smaller size of these veins and their more circuitous course, the catheter size may be restricted depending on the access used. This will limit the usefulness of these approaches in high flow applications such as dialysis.

Azygos and Hemizygos veins

Denny described the placement of a 6 F Broviac catheter into the right atrium using the hemizygos system in a patient with SVC occlusion above the azygos vein and IVC occlusion between the renal and hepatic veins [31] . Venous return was via enlarged azygos and hemizygos veins. The hemizygos vein was punctured under direct fluoroscopic control during contrast injection using a catheter in the left renal vein. A guidewire, catheter, and sheath were advanced through the hemizygos and azygos veins to the SVC and right atrium. A 6 French Broviac catheter was tunneled from the left flank. Its tip was introduced through the sheath and positioned at the junction of the SVC and right atrium.

Intercostal veins

Percutaneous use of the intercostal veins for alternative access has been the subject of several reports. Prior to this, there were reports of intercostal cannulation using surgical cutdown. Meranze et al reported a patient with SVC occlusion between the right atrium and the azygos vein, and occlusion of the left subclavian vein; venous return was through the azygos vein to the IVC [33]. The right subclavian vein had been thrombosed previously and was now recanalized but narrow. A combined surgical and radiological approach was used. A hypertrophied intercostal vein was catheterized through the narrowed right subclavian vein to the SVC and azygos vein. A stone basket was exchanged for the catheter. After surgical cutdown of the intercostal vein over the stone basket, a silicon rubber catheter was grasped and pulled from the intercostal vein to the high flow azygos system. Direct puncture and catheterization of an intercostal vein was described by Andrews [34] . A 19 year old man requiring long-term central access for total parenteral nutrition had occlusion of both subclavian and brachiocephalic veins. Femoral venogram showed occlusion of the external and common iliac veins and the infrarenal IVC. Hypertrophied intercostal venous collaterals were present. A 20 gauge needle and 0.018 inch guidewire were used to puncture a lower left posterior intercostal vein under fluoroscopic control with contrast injection from the femoral vein catheter. A 6.5 French catheter was tunneled from the side and introduced through the intercostal vein, to the hemizygos and azygos veins to the SVC. The procedure was uncomplicated and there was satisfactory catheter function during the six week followup period.

Kaufman et al reported a case of central catheterization from the arm using a chest wall collateral and an intercostal vein [35] . A 27 year old woman with Hodgkin's disease had occlusion of the subclavian and brachiocephalic veins and supra-azygos SVC due to compression from adenopathy. The basilic vein was punctured. Using a hydrophilic-coated guidewire and catheter (Terumo, Tokyo, Japan), a lateral chest wall collateral was catheterized. From there, the third right intercostal vein, azygos vein, and superior vena cava were catheterized in sequence. An arm port with a 5.8 French catheter (PAS Port, Sims Deltec, St. Paul, MN) was placed using this technique.

Access Using Recanalization of Central Veins

The fourth category of alternative access is the use of occluded veins using guidewire recanalization, angioplasty, and stent placement. The use of an occluded vein may aggravate symptoms of venous blockade such as arm, head, or neck edema. Thrombosis may progress after catheter placement. On the other hand, there are many anecdotal reports of successful recanalization and catheter placement using the jugular and subclavian veins. Torosian et al reported the results of a combined surgical and radiological approach in three patients with SVC occlusion with excellent outcome [36] . More recently, Ferral et al reported their results using recanalization of occluded central veins from a femoral approach [37] . Successful access was achieved using the right axillary vein in two, thyrocervical collaterals in two, posterior vertebral vein in one, and the external jugular vein in one. Catheters were used for hemodialysis in four and for antibiotics in two. In their technique, a catheter and guidewire were advanced through the occluded jugular or subclavian vein from the femoral approach. The vein access site was then punctured using a micropuncture kit. The guidewire was grasped using a snare and pulled through the occluded vein. In this manner, through and through access can be obtained, which simplifies vein dilation and catheter placement. This is a technically appealing approach whose long-term success and complications are as yet undefined.

Angioplasty and stent placement has been used to treat venous occlusions and stenosis of various etiologies. This can be applied to venous access as well. Venous strictures can form at the tip of a catheter as a result of local thrombosis or vein irritation. Occlusion of the vein may obstruct the catheter and cause edema. There are many anecdotal reports of treatment of such obstructions using interventional techniques.

Surgical Needles:

There are several types of surgical needles that are available for performing various surgical tasks. A detailed discussion of all the different types of needles is beyond the scope of this summary. However, a basic understanding of the different types of needles is important for anyone performing wound closure. Regardless of the ultimate intended use, all surgical needles have three basic components: the eye, the body, and the point. The eye of the needle is the back end of the needle, which contains the suture material. Most sutures today come with the material pre-attached to the suture needle. The body or shaft is the portion that is usually used for grasping. The cross-sectional configuration of the body may be round, oval, side-flattened, rectangular, triangular, or trapezoidal. The longitudinal shape of the body may be straight, half curved, curved, or compound curved. The most commonly used needles are curved. Curvatures may be 1/4, 3/8, 1/2, or 5/8ths circle. The most commonly used curved needle is the 3/8 circle.

The point of the needle is defined as the extreme tip of the needle to the maximum cross-section of the body. Sharpness of needle point, shape and size are important characteristics. Each specific point is designed and produced to the required degree of sharpness to smoothly penetrate the types of tissues to be sutured. The basic needle shapes are cutting, tapered, and blunt. Cutting needles have at least two opposing cutting edges. These edges are sharpened so that they will cut through tissue that is tough and difficult to penetrate. A conventional cutting needle has two opposing cutting edges with a third cutting edge on the apex of the triangular configuration. The cross sectional shape changes from triangular to flat as it approaches the body. Reverse cutting needles differ from the conventional cutting configuration in that the third cutting edge is located on the outer convex curvature as oppose to the inside concave curvature. This design offers the advantage of having the flat surface closest to the edges of the incision or wound. Thus, the hole left by the needle leaves a wide wall of tissue for the suture to be tied against and reduces the danger of tissue cut out. The taper needle is used primarily on soft easily penetrated tissues, such as peritoneum, abdominal viscera and subcutaneous tissue. This needle is rounded at its tip and tapers to a fine point. These needles are not well suited for penetrating skin or dermal tissue.

Needles vary in size and wire gauge. The appropriate needle diameter as well as needle radius should be chosen to match the size of the wound that requires closure. For closing subcutaneous tissue during the implantation of subcutaneous venous access devices a 26 mm taper needle is ideal. For closure of the dermal layer a 19mm cutting needle is preferred.

Removing Tunneled Catheters

There is an amazing absence of information on this topic, despite the known difficulties. This can be a simple process if thought goes into the placement of the cuff at the time of the initial device procedure. By placing the cuff within 2-3 cms of the skin exit, the cuff and surrounding tissues are accessible to dissection through the skin opening.

If the catheter has been in place for less than a month, it will often be possible to remove it using direct traction, with or without local lidocaine around the cuff. Otherwise, removal using sharp dissection will be required.

A subcutaneous cuff which is within 1 to 3 cms of the skin exit site can be freed by sharp dissection through the exit site opening in the skin. Lidocaine is infiltrated around the cuff through the skin opening. The catheter is retracted, pulling the cuff closer to the exit. Using a pair of small sharp-sharp scissors, the cuff is progressively freed by cutting carefully around the catheter, reaching through the skin opening. The operator must be careful to open and close the scissors parallel to the catheter to avoid inadvertent

transection of the catheter itself, which will tend to make removal more difficult. With cutting and steady retraction, the catheter can be freed in 5 minutes or less. This is an appealing alternative to a number of other Rube Goldberg-ian proposals involving pulleys, weights, and abrupt door closures.
If the cuff is placed deeper in the tunnel than 4 cms, then a small incision will usually need to be made over the cuff; the cuff is then freed using direct exposure and sharp dissection with scalpel and scissors.

Suture Material and Wound Closure

The mainstay of wound closure is suture material. Adhesive strips (e.g. Steristrips) are also extremely useful for skin surface closure and wound edge alignment.

Skin glue, 2-octyl cyanoacrylate, (Dermabond) has been available for a number of years for wound closure, and has found use in a number of applications, including emergency laceration treatment and in plastic surgery. While there is little direct data for the use of skin glue in venous access procedures, many practitioners have begun to use skin glue for wound edge closure during port placement, and for closure of the vein access incision for tunneled catheters. In addition to potentially simplifying the closure process, and saving time, skin glue provides an immediate sterile dressing which is waterproof. Patients may be able to shower or clean within 24 hours after device placement with closure assisted by skin glue. Skin glue may replace subcuticular sutures, or augment them, following port placement. They do not replace deep sutures.

Sutures can be conveniently divided into two broad groups: absorbable and non-absorbable. These two broad categories can be further subdivided into monofilament and multifilament. The monofilament suture is made of a single strand whereas the multifilament suture consists of several filaments twisted or braided together. The monofilament has the advantage of not harboring micro- organisms within the braid of the material, however, its handling and tying characteristics are not as good as the multifilament suture. The size and tensile strength for all suture material are standardized by specific regulations. The diameter of the material is designated by “0”. The more “0”s in the numbers the smaller the size of the strand. Thus 4-0 suture is thinner then 3-0 suture. The accepted surgical axiom is that the tensile strength of any suture need never exceed the tensile strength of the tissue it holds. Thus both the size and the tensile strength of that particular material is important in choosing the correct suture.

Absorbable Sutures

There are several different types of absorbable sutures, which have varying absorption times. These types of suture include surgical gut, collagen, polyglactin, polyglycolic acid, and polydioxanone. Polyglactin is the most commonly used absorbable suture for the closure of skin wounds. This braided material undergoes hydrolysis and is completely absorbed between the sixtieth and ninetieth day. Enzymes are not required to break down this polymer. Only water is required. Thus, synthetic absorbable sutures exhibit a very low degree of tissue reaction when compared to surgical gut or collagen.

Non Absorbable Sutures

A host of non-absorbable sutures have been used for a variety of different surgical closures. These materials include silk, cotton, linen, stainless steel, nylon, polyester, and polypropolene. Each of these sutures have different characteristics which make their use more appropriate in one situation over another. The advantage of non-absorbable sutures is that they maintain their structural integrity for a long period of time and cause very little tissue reaction. The one disadvantage of this material when used to close skin is that they must be removed in time.

Wound Closure

In implanting subcutaneous venous access devices one must be familiar with the closure of subcutaneous tissue and skin. Since the device sits below several mm of subcutaneous fat it is often necessary to close this tissue over the device. There is some debate as to whether this layer of fat

should indeed be closed. One argument maintains that the presence of even a single suture, since it is a foreign body, can increase the risk of infection. On the other hand, if this layer is not closed, a dead space can be left. This dead space can allow the accumulation of fluid, which can delay healing and predispose to the development of infection. In our practice, we recommend closing this layer with an absorbable suture material. The suture material that we most commonly use is a 4-0 suture material which will reabsorb such as Vicryl or Monocryl. The subcutaneous layer is closed to eliminate dead space and also to approximate the wound edges. It is important when closing this layer to ensure that the knots lie deep to the subcutaneous tissues so that they do not interfere with skin healing or cause patient discomfort. To accomplish this, the suture must be inserted into the tissues in a specific fashion. On one side of the wound the needle is initially placed in the tissue from deep to superficial. As it goes across to the other side of the wound, the needle is placed from superficial to deep. Thus, when the knot is tied, it lies facing the deeper subcutaneous tissue.

Subcuticular closure

The subcuticular layer is a layer of tough connected tissue just below the skin. If sutured, this layer will hold the skin edges in close approximation, resulting in a good cosmetic closure. With the subcuticular closure there can be scar expansion over time. However, a simple interrupted skin closure often results in additional scarring as the needle passes through the skin on each side of the wound being closed. Each of these needle passes can result in a small scar and gives rise to the typical railroad track appearance. Since the subcuticular stitch never exits the epidermis no such scarring is noted. Absorbable synthetic sutures whose tensile strength releases in 28 days are ideally suited for continuous dermal closures. In contrast, non-absorbable dermal continuous sutures can be utilized however the end must exit the skin and be removed after wound healing has taken place. In our practice either 4.0 or 5.0 suture absorbable (polyglactin) filament is used. The continuous dermal suture is begun as an interrupted anchoring dermal suture by implanting the first stitch at one apex of the wound. After tying a secure knot, the non-needle suture end is cut short. The next stitch is passed horizontally from the apex of the wound, where the knot was just tied, through the superficial dermis. After exiting the dermis, the position of next bite is identified by pulling the suture across at right angles to the wounds. The needle should enter the dermis and exit the dermis just below the epidermis. Each bite should be less than 3 mm to avoid skin puckering and malposition of the wound edges. When the suture reaches the opposite apex the last suture bite is not pulled through but kept as a loop to form the closure knot. While not essential, it is helpful to pass a stitch back from the apex to the region of the suture loop on the opposite side of the wound so that when the knot is tied the end are directly opposite one another as to avoid skin puckering. Once the knot is tied, the loop is cut away and the remaining portion of the suture containing the needle is passed through the middle of the closed wound and brought out away from the wound through the skin. By retracting on the suture, the knot will pull underneath the dermal layer. Once the skin edges have been approximated in this fashion, one can apply steri-strips to add additional tensile strength and better close the epidermal layer.

Conclusion

In the implantation of subcutaneous venous access devices, the closure of subcutaneous fat as well as skin is important. While skin can be closed with interrupted non-absorbable sutures, this often leads to excessive scarring which can be avoided by closing the wound in a subcuticular fashion. While the subcuticular closure is technically more challenging, it is worthwhile to master this technique as it results in the most cosmetically pleasing result.

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