Central venous catheter placement

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Central venous access has become a vital element of medical care. Fraught with significant complications, traditional surgical approaches have yielded image-guided techniques. This article reviews clinical aspects and devices used, and compares surgical and interventional radiological approaches. It also looks at complications and their management, and aspects of patient care.

The ability to provide routine venous access for medication and diagnostic blood sampling has become a basic element of acute medical care. Central venous access (CVA), both short and long term, is crucial in many areas. Improvements in imaging as well as increased involvement by interventional radiologists has been largely responsible for the major advances in CVA (Adam, 1995).

Historically, central venous catheters (CVC) were designed for haemodynamic monitoring in critically ill patients. Situations where peripheral access is difficult or undesirable have encouraged the development of central venous access devices (CVAD) and techniques for use in ambulatory patients who would have been inpatients previously. Reduced hospital stay and health-care costs and advanced outpatient care have ensued.

PATIENT AND DEVICE SELECTION

Indications and patient selection

Indications for CVAD placement are outlined in *Table 1*.

Absolute contraindications to permanent CVAD placement include evidence of active infection, particularly bacteraemia. Relative contraindications include coagulopathy and thrombocytopenia. These are often correctable to allow placement of an implantable CVAD. In experienced hands, CVA can be achieved in profoundly thrombocytopenic patients with the same rate of complications as a non-thrombocytopenic patient (Ray and Shenoy, 1997). It is therefore important to review the patient's charts, obtain a full blood count and coagulation profile.

Device selection

Matching a CVAD to the patient's needs requires consideration of previous access history and future access needs, type and duration of therapy, the catheter lumina needed and the capabilities of the patient or carers to maintain the device.

CVAD can be divided into temporary, intermediate and long-term devices.

Temporary devices: These are suited for therapies lasting up to 2 weeks, in inpatient or acute care settings. Clinical requirements include high flow rate, large volume infusions or apheresis. Examples include the Arrow® triple lumen catheter and non-tunneled infusion and apheresis catheters. Polyurethane construction affords excellent tensile strength, allowing larger lumens for smaller internal diameters. A variety of sizes, luminal numbers and catheter tips are available. Indications for imaging guidance are uncorrectable coagulopathy, obese or emaciated patients, or where multiple, unsuccessful attempts have been made.

Intermediate devices: Typical examples are peripherally inserted central venous catheters (PICC) and Hohn® catheters.

TABLE 1. Indications for central venous access

Total parenteral nutrition
Requirements for prolonged intravenous therapy
Use of vesicant or irritating agent
Difficult intravenous access
Infusion chemotherapy
Blood transfusions
Frequent blood draws
Haemodialysis
Apheresis
Outpatient intravenous therapy
Haemodynamic monitoring

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PICCs are soft, flexible polyurethane or silicone catheters placed in the upper arm, preferably above the elbow (*Figure 1*). They are easy to place and suitable for adult or paediatric patients. PICCs are similar to CVCs and have lower complication rates. Patients can be managed as outpatients as the catheters are easy to care for. Single (4–5F) or dual (6–7F) lumen varieties are available with end-hole or Groshong valve tip. The Groshong is a two-way slit valve designed to prevent backflow of blood into the catheter when it is not in use. Groshong catheters require less frequent unheparinized saline flushes. PICCs are suitable for highly toxic therapies, long-term antibiotic infusions or total parenteral nutrition for up to 12 weeks' duration, but are unsuitable where high flow rates or large volumes are required. In most centres, PICCs are placed at the bedside by trained venous access nurses.

Imaging guidance is needed where there are no palpable or visible veins, coagulopathy, prior unsuccessful attempts, catheter malposition or malfunction, and in paediatric patients. Significantly higher success rates (100%) have been demonstrated by interventional radiological placement of PICCs compared with bedside placement (82.6%). Bedside placement shows a 17.7% overall complication rate compared to less than 2% for radiological placement, mainly as a result of lower puncture-related complications. Delayed complications of infection (1.9%), inadvertent dislodgment (9.4%) and thrombosis (4.6%) are equivalent (Cardella et al, 1996; Ng et al, 1997).

Hohn® catheters are end-hole, non-tunneled silastic catheters placed via the subclavian vein (SCV), designed for up to 12 weeks' use. Single (5F) or dual (7F) lumen varieties are available with an antimicrobial cuff which is buried beneath the skin. Oppenshaw et al (1994) indicated an infection rate of 1.1 per 1000 catheter days for Hohn® catheters placed in interventional radiology compared with 2–3 per 1000 catheter days for tunneled catheters.

Permanent/long-term devices: These devices are more expensive, require a higher level of skill to place and are preferred where the duration of therapy is expected to exceed 4 weeks. They can be divided into tunneled catheters or subcutaneously implantable devices.

Tunneled catheters: Tunneled catheters can be single or multi-lumen, end-hole or Groshong valve and pass through a subcutaneous tunnel before central vein entry. A dacron cuff is positioned in the subcutaneous tunnel a short distance from the skin entry site permitting tissue ingrowth, which reduces the risk of infection and dislodgment. Some catheters also have a silver impregnated cuff that acts as an antimicrobial barrier. These devices can remain in place for months to years but require some degree of daily maintenance. Tunneled catheters include the Hickman/Broviac group of devices or the haemodialysis catheters (*Figure 2*).

Hickman/Broviac catheters: Hickman catheters are end-hole devices, range from 2.7 to over 12.5F and can be single, dual or triple lumen. Broviac catheters are smaller, 2.7 to 6.6F, single lumen and generally used in paediatrics. The Leonard catheter is a 10F dual lumen catheter that is slightly stiffer than the Hickman. Another modification is the 9F dual lumen Groshong catheter. Designed to reduce the need for daily flushing, several authors have paradoxically found catheter occlusion and flow-related problems are higher with Groshong catheters (Fan, 1998).

Dialysis and apheresis catheters: Catheters for haemodialysis are of large calibre, designed to permit high flow rates of at least 300 ml/min. Construction is usually silastic or polyurethane

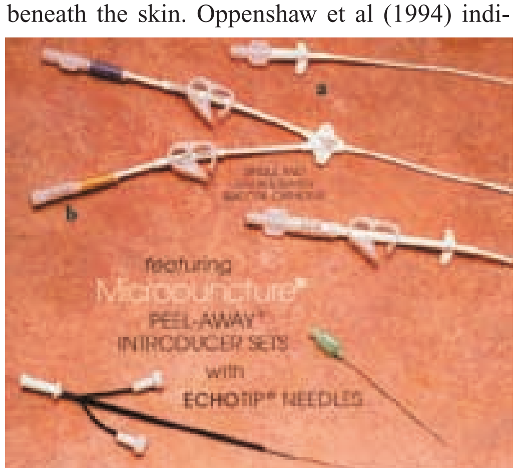

Figure 1. Peripherally inserted central catheters. a. Single and (b) dual lumen varieties are shown. The preferred interventional tools, 21G needle and peel-away introducer sheath are also displayed.

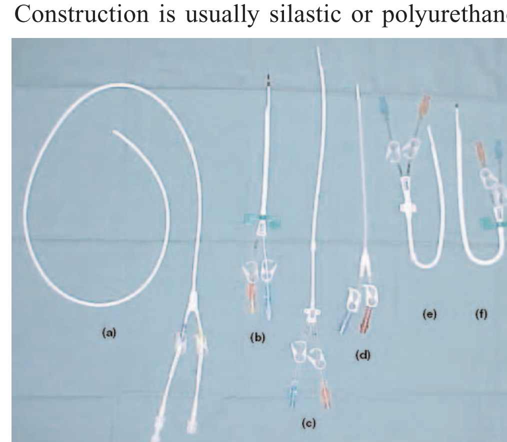

Figure 2. Tunneled catheters. a. Leonard catheter. b. Vascath® temporary dialysis catheters. c. Quinton® PermCath® long-term dialysis catheter. d. Mahurkar® temporary dialysis catheter. e. and (f) Vascath® temporary dialysis catheters.

polymers. Most are dual lumen with staggered end and side holes to prevent admixture of blood at the inflow and outflow portions, reducing recirculation. One device, the Tesio twin catheter system, has two catheters that are placed via separate accesses into the same vein (Trerotola, 1996).

Subcutaneously implanted vascular access devices: Commonly called ports, these VADs require a subcutaneously implanted reservoir. Examples are Pasport®, Infusaport® and Portacath®. These are made of plastic, stainless steel or titanium (*Figure 3*). Plastic devices are easy to place, biocompatible and inexpensive. However, access with metal needles can cause damage, potentially causing premature failure. Metallic devices are more expensive and cause artifacts on magnetic resonance imaging. Ports can be single or dual lumen, 9 to 10F, end-hole or Groshong valve tip. They can be placed in the chest or in the upper arm. Arm ports have now become less popular since the advent of PICCs.

CENTRAL VENOUS ACCESS APPROACHES

Recent advances

Bedside placement of temporary and intermediate CVAD by physicians and venous access nurses is cost effective and usually efficacious. Imaging guidance is reserved for difficult cases. Placement of long-term CVADs has progressed from a surgical cut-down procedure under general anaesthesia to a percutaneous approach under local anaesthesia in the operating room. Imaging guidance is often underutilized, poorly understood or not used at all, especially during venepuncture. Disadvantages to these traditional approaches are long procedure time, compromise of the vein for future use by cut-down techniques, morbidity of general anaesthesia and high costs of operating rooms and anaesthesia.

The use of large bore (18G) needles places surrounding structures, such as pleura and vessels, at risk of inadvertent puncture; this is concerning in patients least able to tolerate a bleeding complication or a pneumothorax. At best, 'blind' techniques have a 95% success rate and a 10% procedure-related complication rate (Ryan et al, 1974; Laméris et al, 1990). From the referring physician's standpoint, venous access is still considered a source of serious morbidity.

Involvement by interventional radiologists has paved the way for considerable improvements in technique, accuracy of placement of CVAD and patient follow-up. Safety, durability, and the diagnosis and control of complications have progressed enormously (Mauro and Jaques, 1993). Success rates of 100%, with 0–2.6% puncture-related complication rates, have been documented (Laméris et al, 1990; Skolnick, 1994). Equivalent infection rates to surgically placed devices, cost benefits and more rapid and timely performance of the procedure are other well documented benefits (Damascelli et al, 1996; McBride et al, 1997).

The ability to detect and manage complications on site, as well as retrieve or salvage malpositioned or malfunctioning devices, places interventional radiologists in a key role. With their familiarity with fluoroscopic and ultrasound guidance, as well as their experience with advanced guidewire and catheter techniques, radiologists are the most appropriate physicians to place CVAD.

Insertion site

A 50% incidence of central venous stenosis has been demonstrated when the SCV is used, whereas the use of the internal jugular vein shows an incidence of less than 10% (Cimochowski et al, 1990). Some authors have documented perforation of the central veins using the right SCV approach (Robinson et al, 1995); however, imaging guidance was little used or not used at all. Duplex ultrasonographic or venographic evaluation of the central veins may be helpful if there has been a history of access failures, surgical or radiation therapy or known anatomical abnormality.

Alternative access sites

If all conventional access sites are exhausted, percutaneous translumbar or transhepatic access to the inferior vena cava can be achieved. Recanalization of occluded veins using various techniques, use of lower limb veins or intercostal veins have also been described (Patel, 1998). These patients represent the extreme and make up less than 1% of the CVA cases. They present a special challenge and should be handled by those who are experienced in advanced CVA techniques.

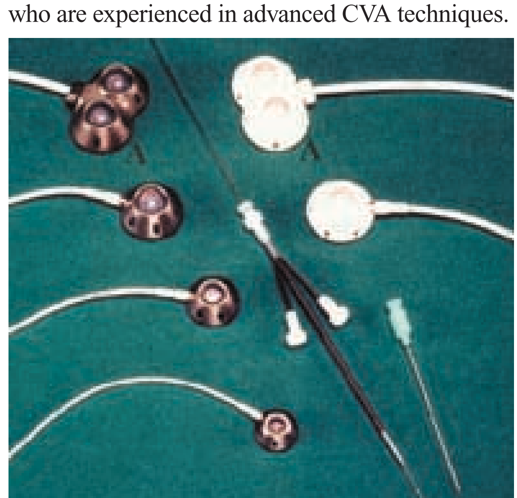

Figure 3. Plastic and magnetic resonance imaging (MRI) compatible metallic ports, single and dual (A) lumen.

PATIENT AND CATHETER CARE

Education of the patient and their carers aims to avoid complications and maintain function of the CVAD. Important issues are catheter flushing, dressings and infection signs. Unnecessary manipulation of the device should be encouraged as it reduces complications (Paplham, 1998).

Catheter care begins at the time of placement by reducing colonization, a key to reducing infection. Skin preparation with chlorhexidine (Maki et al, 1991) and strict aseptic technique is vital and cannot be replaced by the controversial use of prophylactic antibiotics (Elliott et al, 1994). Antimicrobial cuffs and antimicrobially impregnated catheters have been shown to reduce infection rates (Maki et al, 1988); however, increased colonization by Candida has been suggested by others (Flowers et al, 1989). More skilled operators show lower complication rates (Nightingale et al, 1997). Internal jugular vein placements have shown a higher incidence of insertion site infection (Reed et al, 1995).

Chest X-ray after catheter placement confirms position and excludes pneumothorax. Outpatients can be discharged after a brief period of observation, mainly to ensure resolution of sedation. Sterile technique is necessary during flushing, dressing changes and use of the device. Flushing with heparinized saline for end-hole catheters and normal saline for Groshongs is advised. Gauze and tape or the newer semi-permeable dressings offer the highest degree of protection of the catheter exit site from bacterial colonization, compared to occlusive transparent dressings (Ouwendyk and Helferty, 1996). Primarily, dressings should be changed when wet or soiled, then every 5–7 days or as necessary (Moro et al, 1994).

Avoidance of catheter occlusion involves checking for kinks, clamps or suture confinement of the device. Repeated clamp trauma may lead to fracture of the catheter and leakage. Repair kits are available from the manufacturers. Causes of catheter occlusion that will require imaging to diagnose include drug precipitation, catheter malposition, pinch-off syndrome or catheter twisting, catheter thrombosis or venous thrombosis (*Figure 4*). A fibrin sheath or thrombus at the catheter tip causes a ball-valve effect that manifests as an ability to infuse solution but not withdraw blood from the catheter. Injection of contrast under fluoroscopy will diagnose the above problems. Urokinase infusion may help in thrombosed catheters but severely twisted or completely occluded catheters or catheters with pinch-off syndrome will need replacement (Trerotola, 1996).

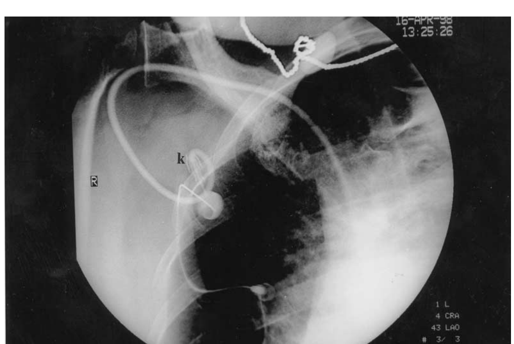

***Figure 4.** Port catheter twisting and kinking (k) present at the first chest X-ray post placement in the operating room. Imaging was improperly used during placement.*

COMPLICATIONS

Complications can be divided into procedural (*Table 2*) and delayed. Immediate complications need early detection and correction as they are often the source of severe morbidity. The use of imaging has significantly reduced most of these complications (*Figure 5*).

Procedural complications

Pneumothorax can be managed expectantly especially if the patient is clinically stable. Serial chest X-rays need to be reviewed. Intervention is only required if there is evidence of tension, enlargement of the pneumothorax or if the patient becomes symptomatic.

Arterial puncture can be devastating, particularly if unrecognized. Air embolism, arterial laceration, mediastinal haematoma and death have been reported (Owens et al, 1998). Treatment usually involves surgery or embolotherapy.

Air embolus is uncommon but potentially serious. Significant air embolus can occur if attention is not paid during venous puncture and exchange of dilators and peel-away introducers. Thankfully, air embolus is uncommon and minor embolic events can be managed by leaving the patient in a supine position with the administration of oxygen, monitoring vital signs continuously.

Arrhythmias, catheter misplacement, inferior vena caval filter dislodgment and failure to gain access is extremely uncommon when imaging guidance is used.

Delayed complications

Surgical and interventional radiological placements show similar infectious and thrombotic complications. Other complications are lower with radiological placement (Trerotola, 1996).

Infection, the most common complication of central venous catheters, has an incidence between 2.8 and 20% (Trerotola, 1996). *Staphylococcus aureus* and *Pseudomonas aeruginosa* are the most common organisms. Infection occurring within

7–12 days of CVAD insertion is usually procedure or peri-procedure related. Infection can occur at the catheter exit site, tunnel or port pocket. Potential sources of infection are colonization of the catheter hub, haematogenous seeding from a distant source, contamination of the infusate and bacterial transport along the catheter track (Elliott et al, 1994). Higher rates of infection have been demonstrated with multi-lumen catheters when compared to single lumen devices.

Immunocompromised patients have an increased risk of infection (Owens et al, 1998). Symptoms and signs of infection include erythema, exudate, pain, and tenderness and induration anywhere along the catheter tract or port pocket. Pyrexia of unknown origin may also indicate line sepsis. A trial of antibiotics in cutaneous infection is worthwhile. However, if improvement is not seen within 48 hours the device should be removed. In cases of catheter-related bacteraemia, the device should be removed and intravenous antibiotics commenced. Explanted catheter tips should be cultured. Placement of a permanent CVAD should be delayed until the patient has been afebrile for at least 48 hours. Ports offer decreased rates of infection compared with other devices.

Catheter-related thrombosis can occur in up to 70% of cases (Owens et al, 1998). It has been suggested that thrombosis and infection are linked (Trerotola, 1996). However, in the absence of signs of infection, low dose urokinase may successfully clear the device. Another cause of thrombosis is a fibrin sheath which forms around the catheter and can be resistant to lysis.

Figure 5. Transverse sonographic image of the neck showing internal jugular vein (v), carotid artery (a) and echogenic 21G needle tip in the jugular vein (n). Note the position of the vein overlying the artery. In this instance, the artery can be easily inadvertently punctured if imaging is not used.

TABLE 2.
Procedural complications

	Blind techniques	Image-guided techniques
Pneumothorax	1–7%	0–1.6%
Arterial puncture	1–8%	0–1.4%
Air embolus	approx 1–2%	approx 1–2%
Arrhythmia	? up to 40%	? up to 10%
Catheter misplacement	2.5–32%	0–1%
Inferior vena caval filter dislodgement	?	?
Failure to gain access	4–33%	0

From: Laméris et al (1990), McBride et al (1997), Owens et al (1998)

Controversy exists as to how to manage this problem; however, exchange of the catheter over a guide wire or replacement of the catheter appear to be the most cost-effective methods (Haskal et al, 1996). Low dose warfarin has been shown to prevent catheter thrombosis (Bern et al, 1990).

Central venous thrombosis, although usually asymptomatic, may be a source of pulmonary emboli in 10% of cases. Treatment with anticoagulation is favoured and catheter removal may be indicated (Trerotola, 1996; Owens et al, 1998).

In cases of central venous erosion, 74% are left SCV placements. Neck, arm or chest pain during infusion should alert the physician to this potentially lethal complication (Duntley et al, 1992).

Fragmentation of the catheter and embolization are often fortuitously discovered on chest X-ray. Catheter fragments often lodge in the heart or pulmonary circulation (*Figure 6*). Percutaneous retrieval by interventional radiologists is the method of choice. Catheter pinch-off syndrome is probably the precursor. This occurs when repeated compression of a catheter by the costoclavicular ligamentous complex in a subclavian CVC results in severe kinking and fracture. It is believed to occur when venous entry is too medial and can be avoided by more lateral puncture using ultrasound guidance (Skolnick, 1994).

Figure 6. Fluoroscopic image obtained during percutaneous retrieval of a piece of introducer sheath (s) from the right pulmonary artery. The sheath was sheared during placement of a venous access device in the operating room.

Catheter migration can result in thrombophlebitis and catheter malfunction. If found early, interventional radiological manipulation can reposition the catheter to its correct position without the need for removal. Migration into the left brachiocephalic vein or internal jugular vein is commonly seen. Uncommon sites of migration include the internal thoracic vein or azygos vein. Thrombus formation around the catheter tip sometimes results in the catheter tip being pushed backwards, resulting in coiling of the catheter at the venotomy site. The incidence of delayed catheter migration and thrombosis has been shown to be lower if the catheter tip is placed at the cavo-atrial junction or upper third of the right atrium (Trerotola, 1996).

CONCLUSIONS

Rapid advances in CVA techniques, catheter design and manufacture have shown to benefit to patients. However, advances in the after care of the devices including education of patients and caregivers by dedicated nursing access teams have had the greatest impact on improved CVAD survival and reduced long-term complications. Despite this, there remains a fear that CVA is a potentially morbid procedure. Involvement by interventional radiology has changed this. Studies have repeatedly shown that interventional radiologists are more successful at CVAD placement and have equivalent or better complication rates than other physicians. Interventional radiology has also shown cost benefits. Justifiably interventional radiologists are gradually assuming the primary responsibility for CVAD placement. HM

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KEY POINTS

- Choosing an appropriate central venous access device depends on the clinical situation, length of treatment and ability of the patient to maintain the device outside hospital.
- Peripherally inserted central catheters are versatile, inexpensive and easy to place and maintain, and ports offer long-term venous access with the lowest rate of infectious complications.
- Imaging has significantly reduced acute, post-procedural complications; however, chronic complications remain a problem.
- Education of the patient and their carers is of paramount importance in maintaining device efficacy and avoiding complications.