Complications of Central Venous Catheterization

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It is estimated that millions of central venous catheters (CVCs) are inserted yearly in US hospitals. The profound impact of the complications associated with CVC use is so important that efforts to minimize and prevent their occurrence should be a routine element of quality improvement programs. This review aims at centralizing the evidence currently available and presenting it as a ready reference that could assist in estimating the magnitude of the problem and formulating prevention initiatives. Additionally, emphasis is placed on the growing body of information that supports the use of ultrasonography-assisted insertion (UAI) as a superior technique to decrease adverse events from CVC insertion. From a clinical and practical point of view, which better correlates with usage issues, CVC complications are best classified as secondary to insertion, indwelling, and extraction practices.

RISK FACTORS

The incidence of mechanical complications is modified by a variety of factors:

1. Inexperience, variably defined but with a consistent relationship between less experience and the rate of complications. 
2. Number of needle passes, with the incidence of complications rising with two venopunctures to a six-fold increase with three or more. 
3. Body mass index > 30 or < 20, previous catheterizations, and severe dehydration or hypovolemia are factors that increase risk. 
4. Coagulopathies do not appear to increase the risk of percutaneous insertion, if appropriate precautions are taken, such as transfusing thrombocytopenic patients with platelets until a count of 50,000 or higher is reached, and fresh-frozen plasma in patients with elevated prothrombin and partial thromboplastin times. Administration of antihemophilic globulin before subclavian vein (SCV) catheterization has led to reports with similar conclusions in patients with hemophilia. Even heparinization does not appear to increase the risk of bleeding or hematoma during internal jugular vein (IJV) insertion. Although coagulopathies are not a clear contraindication, the IJV or femoral vein (FV) appears to be the compressible access site chosen by many authors for patients with coagulation disorders.
5. Large catheter size, such as those used for dialysis, appears to influence the risk of vascular complications of insertion.
6. Failure to catheterize is influenced by factors such as experience, previous catheterizations, previous catheterization attempts, and previous operation or radiotherapy in the anatomic region of interest.
7. Unsuccessful insertion attempts are the strongest predictor of insertion complications. Overall rates of unsuccessful insertion attempts for IJV access have been reported at 12% and 12% to 20% for SCV and IJV in adults and infants weighing < 10 kg. Among patients who fail attempts at catheterization, complications develop in 28%.

Overall incidence

Complications associated with CVC insertion fluctuate according to their definition and the correlation with the multiple factors that influence their occurrence, ranging between 5% and 19%. Femoral catheterization has a higher incidence of mechanical complications than SCV or IJV access, and can be associated with severe injury if an inadvertent femoral artery puncture is too high and is followed by anticoagulation. IJV and SCV catheterization carry similar risks of mechanical complications, although IJV insertion has been reported to have a higher incidence of mechanical complications than SCV in elective and emergency situations. A prospective, comparative study suggests that during cardiac arrest the catheterization success rate can be higher for SCV than for FV access.
Because the complication rate decreases with training,\textsuperscript{27,28} designing a standardized method of CVC insertion\textsuperscript{29} is a logical process to promote prevention and decrease the incidence of adverse events.\textsuperscript{1,30,31} Standardization can also establish management guidelines for some complications that commonly follow CVC insertion, such as pneumothorax.\textsuperscript{32} Standardization can establish a best-practice approach based on evidence, and it can provide an answer to the questions sometimes raised about the competence of house officers.

The advantages of UAI of CVCs have been reported as far back as 1978,\textsuperscript{33} and the body of literature supporting its adoption continues to expand. There is now abundant evidence to establish UAI as the safest method to prevent or decrease overall and specific complications of insertion. Reports of the advantages of ultrasonography over the anatomic landmark method support the findings of risk reduction\textsuperscript{20,34} and improved cannulation success\textsuperscript{20,34-36} for all access sites—FV,\textsuperscript{37} SCV, IJV\textsuperscript{36}—in adults and children\textsuperscript{36,38} and in different settings.\textsuperscript{39} In addition, the gap between experienced and inexperienced operators has been reported to disappear when UAI is used.\textsuperscript{40} Conversely, UAI can be of help to a skillful operator who is otherwise unable to cannulate.\textsuperscript{41} There are reports disputing these results,\textsuperscript{42} although some of the discrepancies have been reported in studies in which ultrasonography was not used in real-time mode.\textsuperscript{6}

**Insertion complications**

Pneumothorax is one of the most common complications of CVC insertion, reportedly representing up to 30% of all mechanical adverse events.\textsuperscript{43,44} Its incidence varies between 0%\textsuperscript{24} and 6.6%,\textsuperscript{45,46} with higher incidences when the number of needle passes increases,\textsuperscript{24} in emergency situations,\textsuperscript{47,49} and when the catheters inserted are large, such as those used for dialysis.\textsuperscript{45} A 1% to 1.5% incidence is more consistently reported.\textsuperscript{6,32,50} Most of the evidence points toward a higher incidence of pneumothorax when the SCV is cannulated, as compared with the IJV.\textsuperscript{5,24} SCV catheterization has occasionally been linked to a lower incidence of pneumothorax than IJV access.\textsuperscript{51}

Delayed pneumothorax has been reported to occur in 0.5%\textsuperscript{44,52} to 4% of the insertions,\textsuperscript{45} but the incidence is quite a bit lower in some studies.\textsuperscript{53} Symptoms commonly appear within 6 hours but not in all patients,\textsuperscript{53} which calls for the need to exercise caution and increased awareness in those cases where the insertion was difficult,\textsuperscript{54} despite the ostensibly easy lack of complications.

A standardized treatment algorithm of CVC-induced pneumothorax can lead to good results with safety, improvements in patients’ comfort, and decreases in length of stay in adults\textsuperscript{32,55-57} and children.\textsuperscript{58} Such an algorithm should include elements of awareness and treatment of reexpansion pulmonary edema,\textsuperscript{59,60} particularly if patients are treated on an outpatient basis.\textsuperscript{57} Re-expansion pulmonary edema is estimated to occur in 1% to 14% of patients with pneumothorax.\textsuperscript{59,61}

Clinician-performed bedside ultrasonography allows the diagnosis of pneumothorax to be made immediately, with a high degree of sensitivity and with better accuracy than supine chest films and equal to that of CT scan.\textsuperscript{62-64} This approach has not yet gained widespread acceptance, is operator-dependent, and patient selection and equipment can influence the results.\textsuperscript{65}

Malpositioning of a CVC has been associated for years with problems of local toxicity, perforation, and venous thrombosis and its sequelae. In the past, a considerable percentage of catheters were left within the right atrium,\textsuperscript{66} but today the consensus in the literature opposes this practice\textsuperscript{67} because of the increased risk of perforation. The debate about the validity of this recommendation continues to surface\textsuperscript{68,69} and many believe that the purported advantages of a CVC tip in the atrium are associated with minimal risks.\textsuperscript{69-71} These disagreements produce difficulties with the interpretation of the true incidence of malposition, particularly if the analysis includes information derived from older series, when the definition of malposition, catheter length, and angle of incidence was not a common element of discussion, and when repositioning was not a major concern.\textsuperscript{72}

Today, malposition includes the recognition that an angle of incidence of the CVC tip against the wall of the vessel $> 40$ degrees carries an increased risk of perforation.\textsuperscript{73} To avoid the tip from abutting against the wall of the vein at an inappropriate angle, it is best to approach left-sided insertions with a 20-cm catheter and the right-sided ones with a 16-cm catheter\textsuperscript{74,75} in adult patients.

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**Abbreviations and Acronyms**

- **CVC** = central venous catheter
- **FV** = femoral vein
- **IJV** = internal jugular vein
- **SCV** = subclavian vein
- **UAI** = ultrasonography-assisted insertion

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Just as catheter length bears a direct relationship to tip position,90 such might be the case as well with catheter diameter and tip malposition in children < 10 kg.77

When a CVC is inserted without image-guided assistance, as it regularly happens, the initial estimate of insertion depth must be made in the clinical setting following unreliable anatomic landmarks. One such approximation is made by premeasuring to a central destination point located just above one-third of the distance between the manubrium and the xyphoid, where the caval-atrial junction can be expected to be. It is common practice, then, to assess the final position of the catheter’s tip radiologically, accepting that the pericardial reflection is below the carina.74 A more precise measurement emerges from the study by Aslamy and colleagues,78 which establishes convincingly that the right tracheobronchial angle is the most reliable landmark to assure that a catheter’s tip is at least 2.9 cm above the pericardial reflection, even if it appears to lie within the cardiac silhouette. Similarly, 20% of catheter tips confirmed to be in the atrial-caval junction by transesophageal echocardiography are still visualized in the midportion of the right atrium on supine chest films.79 From a practical point of view, it is prudent to judge the final position of the catheter in light of the fact that the tip practically always migrates, peripherally, as demonstrated by changes between supine and upright postprocedure imaging.71,80

In general, there appears to be less opportunity for malposition with jugular than with subclavian access.80 Subclavian entry is followed by misplacement of the CVC into the ipsilateral jugular vein in up to 15% of the catheterizations.81 This can be avoided in a major fraction of patients by simply assuring that the J tip of the guidewire is pointing caudad during insertion.82 Additionally, turning the head toward the insertion side narrows the os of the IJV,83 and manual compression of the jugular can avoid misdirection as well while the guidewire is threaded.84 UAI has been reported to be effective in detecting anatomic variants85 and in steering the suction of the right atrium on supine chest films.79 From a geometric echocardiography are still visualized in the midportion of the right atrium on supine chest films.79 From a practical point of view, it is prudent to judge the final position of the catheter in light of the fact that the tip practically always migrates, peripherally, as demonstrated by changes between supine and upright postprocedure imaging.71,80

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Postprocedure films are useful to check for complications and misplacement.81 Congenital anatomic variations can confound the radiologic interpretation of the tip’s location. Of these, the most common clinically significant anomaly of the great systemic veins is the persistence of a left superior vena cava, which is seen in 0.3% of patients; the incidence is higher when cardiac congenital abnormalities are present.88 In children catheterized through a FV, unusual but serious complications secondary to misplacement might be preventable by postprocedure films and contrast injections.89 Pediatric peripherally-inserted central catheters inserted without image guidance require repositioning of the tip in as many as 85% of the patients.90

Vascular injuries during CVC insertion encompass a wide spectrum of complications, with arterial puncture the most common. It occurs more frequently with IJV and FV access than with SCV,50 and even though this complication is usually self-limiting, it should not be dismissed as inconsequential because it can lead to substantial morbidity92 or death,93,94 even if the puncturing needle is of a relatively small gauge95 or the catheter is correctly placed in its intended venous location.96

Puncture of the carotid artery during IJV catheterization attempts averages 6% in prospective studies,97 although higher rates have been reported with the landmark method20,91 and as high as 18% to 25% in infants.71,91 Of greater clinical significance is the fact that up to 40% of carotid punctures are associated with a hematoma; 10 of 25 in one study.20 This, in conjunction with manual pressure, has been interpreted as the mechanism responsible for the appearance of cerebrovascular neurologic deficits97-99 and death.100 Puncture of the subclavian artery during SCV catheterization attempts occurs in 0.5% to 4% of the patients.6,22,50 Hemothorax after CVC insertion is mostly an expression of an inadvertent arterial injury, which has been reported to occur approximately in 1% of central catheterizations,50 sometimes leading to uncommonly severe consequences, such as quadriplegia.101

It stands to reason that the best way to care for arterial perforations during CVC insertion is to avoid them, and the first preventive step to be taken is to recognize that the needle entering the vessel is actually in a vein. More often than not, the operator can rapidly determine that the vessel is an artery because of pulsatile back flow, but that is not always the case. A variety of methods, and their pros and cons, have been described to facilitate recognition of an inadvertent arterial puncture102,103 but none is foolproof. UAI remains the best prevention practice currently available,1,20,35,40 although these advantages are not universally reproduced.104

Large-bore arterial perforation or cannulation of the carotid or subclavian occurs in approximately 0.1% to
1% of cases. Uncommon as it is, this complication is associated with potentially devastating consequences: approximately 30% of these patients can be expected to become symptomatic—bleeding, neurologic findings or other sequelae—and if so, the mortality rate reaches 20% to 40%. Stroke or neurologic deficits associated with large-bore arterial injury can be estimated to occur in 27% of the patients and is reported often, particularly in association with infusions through the cannulated artery. Most arterial large-bore perforations can be attributed to the unsafe manipulation of the dilators, which should only be used to widen the skin and SC tissues but frequently are inserted unnecessarily far, sometimes even causing ventricular perforation. Other possible mechanisms of injury include kinking of the guidewire resulting in misdirection of the dilator and perhaps insertion of the wire outside the vessel.

Arterial puncture and perforation during CVC insertion appears to be mostly a right sided phenomenon, which coincides with the anatomic differences of the vascular system at either side of the midline. On the right, the subclavian-jugular venous junction overlies the subclavian artery, making this vessel more prone to injury than it is on the left. The right SCV enters the innominate at a sharper angle than its counterpart on the left, which would make it then more vulnerable to perforation if a firm dilator is inserted too deeply.

Whatever management choices are made to treat these arterial complications, it is prudent to leave the offending catheter in place until the next step is taken. Individual patient circumstances might dictate the selection of surgical procedure. Thrombin injection, percutaneous suture devices, stent graft placement, or balloon tamponade as the best way to handle these emergencies. Perforation of the aorta during CVC insertion appears in the literature more often than would have been expected, suggesting some degree of underreporting. It sometimes presents with a simultaneous perforation of the superior vena cava. If the perforation occurs within the pericardial reflection there will be an associated cardiac tamponade, in which case the mortality rate reaches 90%. Aortic injuries, as with arterial perforations in general, are also attributable to the improper use of the dilator, although they can also occur with a needle or a large catheter. Most reports of aortic perforation describe multiple insertion attempts and have been right-sided, although a left-sided entry does cause this injury as well. The diagnosis of an aortic injury and the estimation of its extent requires careful assessment, as is the case with any arterial injury after attempted venous catheterization; it is not uncommon for a chest x-ray to be misleading, and often the artery is entered after the vein is perforated. Ultrasonography and CT scanning have been used with success, but the more central the injury the best way to study the damage is a contrast study, if there is time. Both percutaneous closure and balloon tamponade have been described as a treatment approach to aortic injuries.

Injuries to the pulmonary artery result more commonly from the use of pulmonary artery catheters, although occasionally the vessel is punctured directly during CVC insertion attempts. The estimated incidence of pulmonary artery catheter-associated injury—hemorrhage and infarct—is 0.1% to 0.2%, with a mortality rate of 42%. Pseudoaneurysms, AV fistulas and vertebral artery injuries are rare complications of inadvertent arterial perforation or cannulation. AV fistulas can develop shortly or years after catheterization attempts. They have been estimated to occur in 0.2% of IJV, 0.6% of SCV catheterization attempts. Vertebral artery injuries are sometimes associated with acute neurologic injury, but more frequently they have a delayed presentation as a fistula after SCV or IJV attempts, or as a pseudoaneurysm.

The treatment of most pseudoaneurysms of central arteries has evolved into progressively less invasive and effective approaches. Ultrasonography-guided percutaneous thrombin injection has been used in the carotid artery, but this technique is viewed with unease because of its potential for embolization into the cerebral circulation. Similarly, the use of stents to treat pseudoaneurysms and AV fistulas is a reasonable approach if the grafts do not obstruct the takeoff of the vertebral or carotid arteries, although stenting the carotids directly to treat these problems has been successful.

Dysrhythmias accompany CVC insertion fairly often and more so when pulmonary artery catheters are used. Even palpation and pressure on the carotid artery during insertion of a pulmonary artery catheter has resulted in ventricular fibrillation and cardiac arrest.
The incidence of cardiac ectopy during catheterization is clearly related to the guidewire insertion depth, reaching 75% as the wire is advanced between 25 cm and 32 cm from an IJV entry site, the usual finding being the occurrence of premature atrial contractions.153 Ventricular ectopy can be triggered in up to 25% of patients, suggesting the possibility that a malignant arrhythmia could arise.154 Only a small percentage of all arrhythmias are symptomatic155 and almost invariably these difficulties cease after the guidewire is withdrawn. Occasionally, serious problems arise during guidewire insertion in patients at risk, such as a complete heart block,156 and even sudden death.157

Indwelling catheters have been reported to cause arrhythmias in 0.9% of patients, with some necessitating therapeutic intervention in addition to removal.158 Rarely, inserting a guidewire in a patient with an implanted cardioverter device can lead to the most unusual situation of inducing an arrhythmia while delivering a shock to the operator.159

The rarity of serious sequelae and the usually transient nature of the arrhythmias induced by CVC insertion commonly permeate institutional cultures with feelings that these consequences are negligible. In the past, the medical literature reported seeking out ectopy during guidewire insertion and widely considered this as a marker of correct positioning.160 Considering the possibility of inducing ventricular ectopy,154 efforts to avoid overinsertion of the guidewire would be a prudent strategy.

In contrast with CVCs, pulmonary artery catheters induce dysrhythmias in 72% of the patients,141 with ventricular ectopy in 65% to 68% of them.141,152 Three percent of all pulmonary artery catheters have persistent PVCs requiring therapy141 and ventricular tachycardia develops in 1.5%, with one-fourth of these patients requiring cardioversion.140

The neurologic complications of CVC insertion more commonly reported—excluding cerebrovascular accidents—include brachial plexus injury and Horner syndrome. Brachial plexopathies can follow IJV or SCV162 catheterization, and are mostly transient, particularly if the local anesthetic is the cause of the symptoms.161 Multiple punctures or hematoma163 can lead to progressively worsening symptoms resulting sometimes in permanent damage.99,164,165 Typically, IJV insertions are associated with injury to the upper trunk166 and SCV access with the lower trunk166 of the brachial plexus. The incidence of brachial plexus puncutures is approximately 1.7% and can be decreased substantially by UAI.20

Horner syndrome has been reported to occur in 2% of IJV cannulations,111 but this appears to be somewhat high an incidence, inconsistent with the realities of current clinical practice. Other reports describe the syndrome in 2 of 1,000 patients undergoing pulmonary artery catheterization152 and CVC insertions,16 which appears to be a more reliable estimate. This complication is occasionally permanent152 and perhaps likelier to occur with larger-sized catheters,166 and is sometimes coupled with other neurologic manifestations, such as vocal cord paralysis.167

Incidence of lymphatic injuries during CVC insertion is difficult to assess, because most of the available literature is limited to isolated reports, although it is estimated that 25% of overall cases of chyllothorax are a result of surgical injury.168 Chyllothorax and chylopericardium can occur as a complication of venous thrombosis induced by a CVC169-171 or by direct damage to the lymphatic ducts.168,172,173 Traditional thinking suggests that lymphatic injuries are associated with left IJV or SCV insertions and represent thoracic duct damage.168,174,175 Interestingly, a right-sided approach can lead to lymphatic duct harm in adults176 and children.172 Right supraclavicular access has been associated with a 0.5% incidence of lymphocutaneous fistula.177 The supraclavicular approach appears to be associated with a higher than expected rate of lymphatic injury, in the range of 1%,178,179 Notably, UAI does not appear to prevent this complication.174,177,180

Over the past several years, innovative and well–thought-out methods of treating these complications have emerged. Proposed and successfully tried therapies include the use of nitric oxide,181 thoracoscopic fibrin glue application,182 and percutaneous embolization with platinum microcoils.183-185

Guidewire loss during insertion of a CVC is a rare event, occurring approximately twice in several thousand catheterizations.186 Guidewires can loop and become entrapped,187 stick inside the inserted catheter,188 knot and fracture,189 and embolize producing acute arterial insufficiency,190 or paradoxically through a patent foramen ovale.191 Straight-tipped guidewires can cause cardiac perforation.192 Occasionally, a lost wire presents in a most bizarre manner: protruding through the skin.193 Entrapment of a guidewire within a venous cava filter is a serious complication of vascular access that can
lead to displacement or fracture of the intravascular device, but clinician awareness and careful technique could make this a largely preventable problem.194

The cornerstone of safe guidewire insertion is to avoid kinking105,188 and potentially lethal injury,117-120 simultaneously assuring that resistance during insertion or removal is met with cautious response.187 Under these circumstances, the needle-guidewire ensemble must be removed and the procedure reinitiated. To do otherwise substantially increases the risks of wire fracture and its serious sequelae.190,191

Despite admonitions that guidewire loss is a totally preventable situation if the operator makes sure to hold onto the wire during insertion and to inspect it after removal,189,195 these and other precautions are not enough to avoid the problem entirely. An easily inserted guidewire, normally shaped after removal, can still be associated with fracture and embolism196 and multiple films might not demonstrate the complication,197 so the diagnosis of a retained foreign body is commonly delayed.198 Attempts to design a safer guidewire have been reported, with good results.199

Indwelling complications
Infection is the main complication of indwelling catheters, with an incidence of approximately 5.3 per 1,000 catheter days and an attributed mortality of 18% (0% to 35%).200 Most infections arise from the skin insertion site or the catheter hub, depending on the indwelling time, and are then perpetuated by biofilm, a bacterial-derived community embedded in a matrix of extracellular polymeric substances that they produce.201 This determinant factor could explain the favorable results seen with the injection of hydrochloric acid to treat CVC infections.202

FV catheters have a higher risk of infection than SCV or IJV catheters,1 as do noncuffed catheters compared with cuffed ones.200 Because the risk of infection is heightened by thrombosis,203,204 efforts to render the catheters less thrombogenic have included heparin-coating, but the risk of activating heparin induced thrombocytopenia makes their use imprudent.205 Catheter-related bloodstream infections can be prevented: in an elegantly designed study, Berenholtz and colleagues206 instituted sequential measures in an ICU population, bringing the incidence of infection down to virtually zero. Currently, this “bundle” of standard actions includes educating caregivers in hand hygiene, chlorhexidine preparation, use of full sterile garb precautions, and CVC removal as soon as possible. This educational module includes a checklist to ensure adherence to evidence-based guidelines.206,207 Other preventive measures found to be effective additions to the previously mentioned bundle include voiding routine catheter exchanges and the use of antibiotic ointments on the entry site, plus the use of chlorhexidine impregnated sponges to dress the insertion area.200 Some studies suggest that adhering to these measures eliminates the difference in infection rates seen in all three insertion sites.208 Gram-positive infections and those involving implanted reservoirs practically always require removal of the catheter.209

The use of antimicrobial impregnated catheters is still debated by some authors,210 and the Center for Disease Control and Prevention guidelines recommends the use of antimicrobial-impregnated CVCs in selected clinical situations,200 but a strong body of evidence justifies their use.207 In a persuasively written viewpoint, Crnich and Maki207 provide an excellent summary of the numerous sound studies demonstrating that a substantial number of blood stream infections can be prevented—40% at least—with the use of short-term antimicrobial-impregnated CVCs.

Thrombosis induced by CVCs is a frequent occurrence, ranging between 33%1 and 59% of indwelling catheters, although clinical symptoms develop in just a small percentage of patients.211 The pathogenesis is multifactorial, but endothelial injury, turbulence of the venous flow and catheter thrombogenicity211 play a role, as does the composition of the infusate212 and the characteristics of the disease process. A fibrin sheath develops within 24 hours of catheter insertion, and although this sheath contributes to catheter occlusion, it does not predict subsequent deep vein thrombosis of the vessel,203 but all CVCs are subjected to malfunction as a result of this fibrin casing.213

The rate of CVC-induced thrombosis is lower for SCV than for IJV and FV access.1 The rate of thrombosis is reported at 1.9% for SCV access22 and 22% to 29% after 4 to 14 days of indwelling time214 for a femoral CVC.22,204 Location of the CVC tip within an inlet vein increases the likelihood of catheter-associated thrombosis 16 times,215 but malfunction is lessened when the catheter lies in a high-flow central vein.214 Superior vena cava obstruction can be a substantial problem, estimated to occur in 1/1,000 indwelling devices.217
Varying degrees of occlusion induced by CVCs are associated with varying degrees of stenoses, although as many as 30% of the patients without previous catheterizations might have clinically significant venous anatomic abnormalities—greater than 50% stenoses and angulations—that could increase the risks of catheterization. Twice as many patients—60%—will have de-angulations—that could increase the risks of catheteriza-

tions might have clinically significant venous an-

omalies, greater than 50% stenoses and higher if the CVC has been infected. Narrowing develops mostly behind the clavicle, an area difficult to visualize with ultrasonography.

In cancer patients, CVCs cause vessel thrombosis in 41% of the patients, with postphlebitic syndrome developing in 15% to 30% of them and pulmonary embolism developing in 11%. Morbidity and mortality of jugular and subclavian thrombosis appears to be similar. Although treatable, longterm relief for central venous occlusive disease is rarely achieved. Despite this, the consensus in the medical literature indicates that routine antithrombotic therapy for oncologic patients with CVCs is not warranted, a conclusion that is likely applicable to patients without cancer.

Fibrin sheath stripping and urokinase infusion work equally well to salvage catheter patency, and appropriate differentiation between a fibrin sheath and thrombosis is necessary before the initiation of therapeutic maneuvers. There is increasing interest in endoluminal brushing as a method to regain patency of occluded catheters.

Vascular erosion and perforation of an indwelling CVC can be associated with cardiac tamponade, depending on whether the perforation occurs below or outside the pericardial reflection. Perforation without tamponade occurs in 0.4% to 1% of catheterizations, with a resulting mortality rate of 12%. Erosion followed by tamponade is estimated to take place in 0.2% of patients, with an associated mortality rate of nearly 90%. Use of peripherally placed catheters in neonates carries an overall reported mortality rate of 0.7%, because of the disproportionate higher risk of cardiac tamponade with these type of lines. Although perforation without tamponade can present as a hemothorax, it manifests most commonly as a hydrothorax, which is bilateral in up to one-third of patients.

A useful predictor of impending perforation is the radiographic confirmation of a curled-up catheter tip, which occurs in approximately 4% of placements, and sometimes requires a lateral chest film for visualization. Myriad reports discuss the likelihood of perforation by indwelling catheters as a function of the entry side, because most of the cases reported have been associated with left-sided CVC insertions, which results in a more horizontal position of the catheter shaft and abutting of its tip against the vein wall when the catheter is of insufficient length. The pathogenesis of this complication must be attributed to the steady pressure and friction exerted on the vessel wall by the catheter tip eventually leading to erosion, the same way a decubitus ulcer forms. So, abutting the vein wall or curling of a catheter tip that does not normally have a curvature, is basically a signal that the CVC tip is compressing the vein and should be repositioned to lie parallel to the vessel wall by whatever maneuvers are required. Unfortunately, this cannot always be accomplished by staying above the pericardial reflection.

This information then leads to the simple question of why is it that pigtailed venous catheters are not being used more often? In an intelligently conceived study, Gravenstein and Blackshear demonstrated that a pigtail catheter is 100 times less likely to perforate than straight-tipped catheters. There is also additional compelling evidence to support the use of pigtail catheters: studies in a porcine model have shown that central access with looped catheters can eliminate the vein wall injury process for substantial periods as compared with straight catheters. This also suggests that a thrombus at the tip of the catheter—a common cause of dysfunction—might be less likely to develop if the tip does not lie in direct contact with the vein wall. So far, clinical experience with catheters contoured in this manner is limited but favorable.

Catheter fracture and embolization is reported to occur in 0.5% to 3% of patients with indwelling CVCs. Embolization can lead to arrhythmia with cardiac arrest, pulmonary embolism with hemoptysis, perforation, thrombosis, and infection, for an overall morbidity rate of 71% and a mortality of 30% to 38%. Compression of the central catheter between the clavicle and the first rib causes the pinch-off syndrome, clinically manifest by a functional occlusion
linked to postural changes. The mechanical shearing forces on the catheter can, over time, lead to fracture and embolization. This syndrome is estimated to occur in 1% of patients,\textsuperscript{248} and it is important to differentiate it from other causes of catheter obstruction, which can be done by detecting telling radiographic findings. Because raising the arms or shrugging opens the costo-clavicular angle, the films should be taken with the patient upright and with arms by the side.\textsuperscript{248,249} Catheter fracture can also occur by shearing from the insertion needle or during extraction.\textsuperscript{250} This information suggests that a safer way to remove a SCV catheter should include elevation of the patient’s arm as traction is applied.

**Extraction complications**

Although air embolism can occur during insertion of a CVC,\textsuperscript{251} it is perhaps more commonly seen as a complication of catheter extraction.\textsuperscript{252} It is reported to occur in 0.13%\textsuperscript{251} to 0.5%\textsuperscript{2,253} of CVC insertions, with tunneled catheters inserted through a peel-away sheath a likelier source of this complication.\textsuperscript{251} The associated mortality is substantial, ranging between 23%\textsuperscript{252} and 50%,\textsuperscript{254} often if not always connected to neurologic deficits of varying degree.\textsuperscript{255}

One-hundred milliliters of air can pass through a 14-gauge needle in 1 second,\textsuperscript{255} so it is imperative to be aware of this possibility during cannulation of any vessel and during catheter exchanges and removal.\textsuperscript{256} Air embolism has occurred during accidental hub disconnection,\textsuperscript{257} through a residual catheter track,\textsuperscript{258} as a worrisome factor during home infusion therapy,\textsuperscript{259} and has been reported to lodge in the coronary circulation.\textsuperscript{260} It is occasionally a result of inadvertent arterial cannulation, in which case, neurologic sequelae are frequent. During venous catheterization, the path leading the air embolus to produce a cerebrovascular accident appears to be mostly by pulmonary shunting or through a patent foramen ovale.\textsuperscript{252,261} When air embolism is recognized, if the usual therapeutic maneuvers—left lateral Trendelenburg, air aspiration, 100% oxygen—are not effective, hyperbaric oxygen treatment could be of help.\textsuperscript{262} Improved designs of protective insertion sheaths appear capable of decreasing the incidence of this grave complication.\textsuperscript{263} Technique standardization should include education about prevention of air embolism during CVC insertion\textsuperscript{264} and removal.\textsuperscript{255,264}

Other extraction complications include breakage,\textsuperscript{265} separation from the hub,\textsuperscript{246} and knotting of the catheter\textsuperscript{266,267} or guidewire.\textsuperscript{268} Breakage is frequently a result of excessive traction force,\textsuperscript{246} although the catheter material can sometimes be faulty and ruptures or dilates.\textsuperscript{269} Accidental CVC removal is a serious problem because of the associated risks of hemorrhage and air embolism, and it occurs between < 1% and 7.5% in ICU populations\textsuperscript{270,271} and in children.\textsuperscript{269} Rarely, extraction of a CVC placed in the ipsilateral side of a patient with an AV fistula for dialysis can lead to hemothorax.\textsuperscript{272} Central catheters attached to the vein are more commonly a consequence of dwell time\textsuperscript{273} and the constellation of histologic changes associated with fibrin formation.\textsuperscript{274} Occasionally, a stuck catheter might be a result of fractures in the material.\textsuperscript{275} This complication has been reported in adults,\textsuperscript{276} children,\textsuperscript{277} and with peripherally inserted lines.\textsuperscript{278}

**Technical considerations and discussion**

Over the years, a plethora of reports and adjunct commentary have highlighted the myriad complications that can befall patients receiving a CVC, in an effort to emphasize effective prevention opportunities. In this context, UAI can help the operator decide the relationship between artery and vein,\textsuperscript{41,279} how often the venous anatomy is abnormal,\textsuperscript{280} which vessel is best to use,\textsuperscript{281} how much the head should be turned,\textsuperscript{282} and the effect of patient position on the diameter of the vein.\textsuperscript{283}

UAI is not infallible, and certain complications and precautions require constant operator alertness. Arterial puncture, for example, can still occur with UAI,\textsuperscript{26} and the methods described to ascertain if a catheter is inside an artery are not foolproof, but they are reasonable and effective. Routinely measuring blood gases or attaching the catheter to a transducer is not always practical, nor can physicians realistically be expected to use these techniques on every patient. A simple method to detect arterial placement might be to return to the standard of running saline solution through the line before using a volumetric pump,\textsuperscript{112} a practice that perhaps can be resuscitated as part of a standardized method of insertion.

Final position of the CVC tip is particularly important in relationship to the complications seen with an atrial location, or when the tip is curled on itself\textsuperscript{236,237} and exerts pressure against the vessel’s wall. Regardless of how rational some arguments in favor of an atrial location might be, the sine qua non of any procedure is patient’s safety, and the mortality of an atrial perforation and tamponade makes any such debate a rather gratu-
The site of insertion remains an issue of discussion and varied preferences, but in terms of infection prevention the consensus points toward the SCV as the better route of access. The agreement is not as clear in terms of prevention of mechanical complications, particularly in the areas of malposition and pneumothorax.

Side of insertion also remains a contested theme. Many believe that left-sided insertions are burdened with a higher probability of superior vena cava perforation than access through the right side, although the important element of catheter length and its relationship to this problem is not always emphasized. Others present good evidence that right-sided SCV and IJV insertions are likelier to induce arterial injury, although the left side offers a smoother and more obtuse angle of subclavian approach. A left-sided approach is reported to be associated with less technical difficulty and complications in a statistically significant number of patients.

Ultimately, physicians should be cognizant of the many complications associated with CVCs, recognizing that the sheer volume of lines used is substantial enough to convert a rare problem into one they will be likely to experience. With this in mind, prevention of even the most unusual complication becomes a worthwhile initiative. The weight of evidence in favor of UAI to decrease the incidence of mechanical complications suggests that this kind of image-guided approach to CVC insertion should be made available routinely.

REFERENCES

60. Sue RD, Matthey MA, Ware LB. Hydrostatic mechanism may contribute to the pathogenesis of human re-expansion pulmonary edema. Intensive Care Med 2004;30:1921–1926.


226. Gray RJ, Levitin A, Buck D, et al. Percutaneous fibrin sheath stripping versus transcatheter urokinase infusion for malfunc-


