The Risk of Inadvertent Arterial Cannulation During Central Catheter Placement

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Background

Patients and clinicians depend upon central venous catheters (CVCs), including peripherally inserted central catheters (PICCs), to deliver vital forms of therapy. CVCs provide reliable venous access for delivering total parenteral nutrition (TPN), chemotherapy, antibiotics, pain medication and other medications/fluids, especially for long-term, very ill patients. Unfortunately, central venous line placement is not risk free. Among potential complications are those caused by inaccurate placement of the central catheter.

Inadvertent arterial puncture is a serious and often fatal complication that can occur during this procedure. If the tip of a CVC is inadvertently placed in an artery, the major complications that can result encompass mechanical injuries, such as perforation and erosion by the catheter tip, and injuries caused by intra-arterial infusion of caustic medications and other solutions. Inadvertent arterial cannulations are reported in literature from between 0.2% to 1.0% of all insertions. With 6 million annual procedures, there is a potential of 60,000 inadvertent arterial punctures annually.

Inadvertent arterial cannulation can be detected by brightness of the blood color and the projectile flow. This is not always a reliable confirmation when a patient is hemodynamically unstable, therefore the central catheter remains in an artery.

The “gold standard” test for confirming that a central catheter tip is correctly placed has been a chest X-ray. In medical testing, the term “gold standard” refers to the best-performing test available. However, chest X-rays are not always a reliable method for preventing or readily detecting inadvertent arterial cannulation.

The Causes of Inadvertent Arterial Cannulation

Inadvertent arterial cannulation occurs for a variety of reasons. The standard method of central line insertion is a blind landmark technique. The clinician will normally guide the insertion with anatomical landmarks on the patient’s body. These are known to be unreliable for an activity requiring as much precision as central line insertion does.

Another cause, is inexperience of the clinician inserting the line, which has a consistent relationship to complication rate.[1] In fact, unsuccessful insertion attempts, which are in many cases related to inexperience, predict insertion complications more accurately than any other factor. It is logical to assume that inexperience may be a growing risk factor, with many hospitals declining to employ dedicated vascular access teams.

Body mass index of the patient also has an impact on the insertion complication rate. A body mass index greater than 30 – in other words, obesity – increases the risk of mechanical complications.[7] Among other variables that affect the risk of inadvertent arterial cannulation are the number of needle passes, the targeted insertion site, catheter size, and whether or not the case is an emergency. However, it is beyond the scope of this paper to discuss how each of these factors is related to the complications discussed below.

The method used to guide the insertion process substantially affects the complication rate. Ultrasound guidance for central line placement is associated with fewer attempts and fewer complications,[4] and is recommended by the federal Agency for Healthcare Quality and Research and the American College of Emergency Physicians. Ultrasound can significantly mitigate the negative impact of clinician inexperience discussed above.[7] Numerous experts, after examining case reports, have concluded that while ultrasound significantly reduces the chances of inadvertent arterial cannulation, it does not eliminate them.[9]

Despite the supporting evidence in favor of ultrasound guidance for central line insertion, the guidelines are often not followed. In many facilities where central lines are inserted, the equipment isn't even available. When it is available, some clinicians continue to use the blind landmark technique to insert central lines.

Pressure waveform monitoring is another technology used to guide central line insertion. It can be used by itself or in tandem with ultrasound. Like ultrasound, however, it does not entirely prevent inadvertent arterial cannulation even though it is undeniably helpful.[2]

Reported Complications

Inadvertent arterial injuries occur in about 1% of CVC insertions overall, according to Roberto E. Kusminsky, MD, MPH, FACS, whose article "Complications of Central Venous Catheterization" is a key resource on this subject.[7] The most common vascular injury caused by a CVC insertion is arterial perforation. The consequences are usually not serious, but in some cases the use of a relatively small-bore needle is associated with considerable morbidity and death.[7] Inadvertent perforation of an artery by a large-bore needle can also lead to catastrophic or fatal injury. Perforation or cannulation of the carotid or a subclavian artery happens infrequently (roughly 0.1% to 1.0% of cases[7]), but 30% of those cases are symptomatic and for that subset, the mortality rate is 20% to 40%.[7] Large-bore arterial perforation has led to stroke or other neurologic deficits in an estimated 27% of cases, notes Kusminsky. This is especially true when fluids have been infused after the inadvertent cannulation occurred.

Below is a partial list of inadvertent arterial cannulation-related complications reported in the literature. All involve accidental infusions into an artery:

CVC Complications	PICC Complications	General Complications Reported
Hemorrhage[1]	Embolic stroke with heft hemiparesis due to exposure of cerebral circulation to TPN[4]	Direct mechanic al obstruction and occlusion of artery[6]
Pseudoaneurysm[1]	Arterial thrombosis proximal to PICC insertion site[4]	Intra-arterial medications can induce vascular injury, vasospasm and muscle necrosis[6]
Arteriovenous fistula[1]	Thromboembolectomy performed to brachial artery[4]	Need for thrombectomy[6]
Death from carotid artery placement[1]	Arterial angioplasty[4]	Need for fasciotomy due to compartment syndrome[6]
Blindness from TPN crossing blood brain barrier[3]	Arteriovenous fistula[4]	Gangrene[6]
Perforation of aorta[2]	Cerebral infarct (stroke) in a pediatric patient [5]	Arterial thrombosis requiring anticoagulation (and complications associated with its administration)[6]
Carotid artery dissection[1]		Ischemia of hand/fingers resulting in amputation of digits or extremity[6]
Quadiplegia[1]		Air embolus (due to combination of arterial cannulation and inadvertent injection of air)[3]
		Fat emboli (with TPN administration)[3]
		Paresthesia, severe pain, motor dysfunction[3]

The Inadequacy of Confirmatory Chest X-rays

It is important to acknowledge that chest X-rays became the gold standard for confirming CVC tip position because they are acceptably accurate most of the time. But clearly, given the complications just discussed, “most of the time” is not sufficient. The inadequacy of chest X-rays for this purpose begins with the fact that they are static images that take place after an insertion is completed. By then, an injury may have already occurred. A dynamic guidance technology that accurately guides insertion in real time would be more beneficial, particularly if it was reliable enough to make chest X-rays unnecessary.

Additional support for the inadequacy of X-rays comes from Hostetter et al. which also notes that confirmatory chest X-rays are becoming increasingly obsolete as the target area for CVC insertions has evolved.[4] In an earlier era when the preferred target area encompassed the entire superior vena cava (SVC), a confirmatory chest X-ray accurately portrayed tip position. Today, however, clinicians tend to target the **lower 1/3 of the superior vena c**ava (SVC), cavo-atrial junction (CAJ), which is a smaller area to target at an average length of 2.33 cm. Therefore it is harder to identify actual tip position on an X-ray because the borders of the SVC-CAJ aren’t visible on the film. This increases the likelihood that interpretation of the X-ray may vary from one reader to the next. No reliable interpretation methods have been found to completely compensate for this problem.

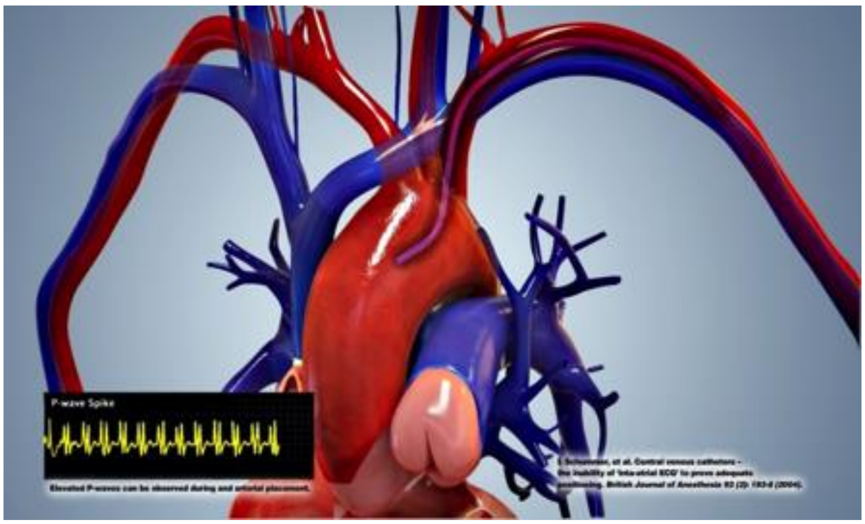
Hostetter and colleagues list other problems with confirmatory chest X-rays. They can be hard to interpret if the X-ray includes other objects inserted into the patient such as a pacemaker, wires from an automated implantable cardioverter-defibrillator, or other CVCs. The patient’s own anatomy can complicate the interpretation, too. Morbid obesity is one condition that will contribute to this problem.

Chest X-rays also compromise patient safety in ways that don’t directly involve accurate placement. Most obviously, they expose patients to radiation that can affect their long-term welfare. Additionally, they can delay therapy because they can take up to several hours to schedule and read.

Finally, confirmatory X-rays can cause operational problems for a medical facility. Nurses can spend hours waiting for the results to see if a CVC needs to be re-positioned. Patients are also inconvenienced by the waiting, and the re-positioning, if needed. The hospital may appear inefficient and outdated to them if they are aware of other institutions where these issues don’t seem to occur. This may affect their willingness to be treated at the hospital in the future or recommend it to others.

Case Study:

Several tip positioning technologies are available to clinicians. One technology for catheter tip placement utilizes ECG, noting the P-wave spike as a criteria for determining acceptable tip placement. According to Schummer: "ECG Guidance is unable to distinguish between venous and arterial catheter placement"[11]. Furthermore, Schummer postulated and proved that pericardial reflection, rather than entry into the right atrium, is responsible for the P-wave changes, thus proving ECG-alone technology is unable to detect arterial versus venous catheter placement.



Arterial puncture with catheter placement. P-wave spike is present due to pericardial reflection, not entry into the SVC.

In order to test the P-wave spike when a catheter tip is arterial, testing was performed with the ARROW® VPS® Vascular Positioning System®. The ARROW® VPS® Device is a novel technology utilizing Intravascular ECG and Doppler to determine catheter positioning while advancing a central catheter. This system uses a proprietary algorithm that displays in the form of symbols on the screen to alert you to positioning errors. In addition to the symbols, the clinician is able to note ECG and Doppler changes throughout the case.

Ten swine were used in a lab setting to test the accuracy of the VPS® Device to detect arterial versus venous catheter placement. Using fluoroscopy and VPS® Technology guidance, catheters were inserted through the external jugular vein into the CAJ. A second catheter was placed through the carotid artery and threaded to the ascending aorta. Doppler and ECG were monitored and recorded using the VPS® Device. With all ten arterial placements, the VPS® Device exhibited a P-wave spike as the catheter approached the aorta. These results were similar to the Schummer study,[11] All ten arterial placements accurately displayed the correct Doppler readings as retrograde flow, and the orange symbol was appropriately displayed.

Conclusion

The literature documents numerous serious complications that can occur when central catheter tips are inadvertently placed in an artery. Some of these complications have resulted in patients' deaths and left others seriously harmed for life. Medical institutions can be subject to these risks if they routinely rely upon chest X-rays to confirm proper tip placement. Hospitals should acquaint themselves with the evidence about CVC insertion-related complications and consider either supplementing or replacing confirmatory chest X-rays with an effective dynamic guidance technology.

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