

Central Venous Catheter Tip Position: A Continuing Controversy

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There is continuing debate among physicians, nurses, and federal regulatory agencies regarding the correct position for the tip of a central venous catheter. The traditional approach has been to place the catheter tip within the superior vena cava. However, many interventionalists believe that the performance and durability of the catheter will be improved by positioning the catheter tip within the upper right atrium. Recently, this variability in clinical practice has become an increasingly divisive issue among physicians who insert these catheters and nurses who use them. This article is intended to elucidate the controversial issues and provide a brief review of the extensive literature on this important topic.

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Abbreviations: FDA = Food and Drug Administration, K/DOQI = Kidney Disease Outcomes Quality Initiative, PICC = peripherally inserted central catheter, SVC = superior vena cava

OPTIMAL positioning of the tip of a central venous catheter is a complex and controversial subject. A review of the scientific literature on this topic reveals strong opinions and conflicting clinical practices. At the center of this highly charged debate is the safety of positioning the tip of a central venous catheter into the upper right atrium. The United States Food and Drug Administration (FDA) and several national nursing societies strongly disagree with this practice because of the potential for cardiac-related complications. Recent discussions among members of these national nursing organizations have suggested that this issue may become increasingly contentious in the future.

BACKGROUND

In 1989, the FDA published a precautionary statement regarding the

positioning of central venous catheters that states that "the catheter tip should not be placed in or allowed to migrate into the heart" (1,2). In 1996, the Oncology Nursing Society (3) published access device guidelines that restated the FDA recommendations that a catheter tip should not be positioned within the right atrium. In 1998, the National Association of Vascular Access Networks (4) published a position statement with regard to positioning of peripherally inserted central catheters (PICCs). This group recommends that the tip of a PICC should be positioned within the lower third of the superior vena cava (SVC), close to the junction of the SVC and right atrium. In 2000, the Infusion Nurses Society published a Standards of Practice document that states that "central catheters should have the distal tip dwelling in the vena cava" (5).

Nurses who specialize in vascular access or infusion therapy are now taught not to use a central venous catheter if the tip is positioned within the right atrium. They are told that if they use this "malpositioned" catheter, they could be held liable if a complication occurs. Therefore, nurses are placed in a difficult situation when they learn that their patient has a catheter with its tip located in the right atrium. Should they knowingly break

their own standards of practice guidelines?

The National Kidney Foundation has published well-recognized guidelines that are somewhat in contradistinction to those recommended by the FDA and the nursing societies. The 2001 Kidney Disease Outcomes Quality Initiative (K/DOQI) Clinical Practice Guidelines has two separate recommendations, one for tunneled hemodialysis catheters and one for nontunneled hemodialysis catheters (6). The K/DOQI guideline for tunneled (cuffed) catheters states that the tip should be positioned at the SVC/right atrial junction or into the right atrium to ensure optimal blood flow. With regards to temporary or nontunneled hemodialysis catheters, the K/DOQI recommendation is to position the catheter tip at the SVC/atrial junction or in the SVC.

In 1997, the Standards of Practice Committee of the Society of Cardiovascular and Interventional Radiology published "Quality Improvement Guidelines for Central Venous Access" (7). This document does not specifically discuss catheter tip positioning. However, these guidelines define a successful catheter placement as "introduction of a catheter into the venous system with the tip in the desired location and the catheter functions for

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its intended use." This statement would suggest that final positioning of the catheter tip is at the discretion of the operating physician. In 2000, the SCVIR Technology Assessment Committee published "Reporting Standards for Central Venous Access" (8). This document provides a short discussion pertaining to catheter tip positioning and states that "[t]he ideal tip location for central venous access catheters has yet to be determined."

The crux of this controversy is the concern for patient safety versus the desire for optimal catheter performance. Physicians and nurses who oppose the placement of central venous catheter tips into the right atrium can provide substantial scientific support for their viewpoint. There are numerous reports describing complications attributed to central venous catheter tips positioned within the right atrium. These complications include cardiac perforation and tamponade, cardiac arrhythmias, and catheter-induced thrombosis (9–11).

Proponents of placing catheter tips into the right atrium contend that this practice provides optimal performance and superior functional durability when compared to catheter tip placement into the SVC. However, there are few published studies that support these beliefs and the SCVIR guidelines provide minimal, if any, support for right atrial positioning. Therefore, the burden of proof is on the advocates of this practice to provide clinical data to support the safety and superiority of placing catheter tips into the right atrium.

Unfortunately, a critical analysis of the scientific literature is complicated by the lack of uniformity in nomenclature, investigational methods, and reporting standards. The identification of catheter-related complications is often dependent on the method used for diagnosis. Therefore, it is not surprising to learn that different studies using different diagnostic methods have conflicting results. Another common problem is the failure to distinctly separate those complications that occur during the catheter insertion procedure from those that are caused by malposition of a catheter tip. As with many complex and controversial issues, the results of different clinical studies are discordant and the interpretation of results is subject to the

investigator's bias. To better understand the different opinions regarding catheter tip positioning, a review of the relevant scientific literature may be useful.

ANATOMY AND IMAGING

The tip of a central venous catheter is traditionally placed within the SVC. Subsequently, a standard anterior/posterior chest radiograph is often obtained to assess the location of the catheter tip. However, the radiographic borders of the SVC and SVC/atrial junction have not been well defined. Therefore, the determination of catheter tip position with chest radiography is often imprecise and subject to interobserver variability.

Various radiographic landmarks have been used to help identify and define the cephalad and caudal boundaries of the SVC (12). Defalque and Campbell (13) stated that, when viewed on a standard chest radiograph, the ideal position for a catheter tip is between the fifth and sixth thoracic vertebrae. Greenall and colleagues (14) stated that the inferior border of the clavicles corresponds to the origin of the SVC and that the tip of a central venous catheter should be positioned below this anatomic landmark. However, as described by Aslamy and colleagues (12), these skeletal structures are not located in the same anatomic plane as the SVC. Therefore, as a result of the effect of parallax, the use of these structures as radiographic landmarks can lead to substantial errors in tip positioning. To decrease or eliminate the effect of parallax, an anatomic structure that is located in close proximity to the SVC would be a better radiographic landmark for catheter positioning. Rutherford et al (15) reported that the upper border of the SVC can be defined by the angle of the right main bronchus and the trachea. This angle is usually visible on chest radiographs and represents a good anatomic structure to delineate the upper border of the SVC.

Localization of the inferior border of the SVC and the SVC/atrial junction with use of radiographic landmarks is imprecise and open to interpretation. When viewed on a standard chest radiograph, the right lateral wall of the SVC defines the right lateral border of the mediastinum. Inferiorly,

the right lateral border of the cardiac silhouette is defined by the right atrium. A widely held belief is that, when viewing a standard chest radiograph, the SVC/atrial junction is located at the intersection of these two structures; the right lateral margin of the SVC is followed inferiorly to its junction with the superior border of the cardiac silhouette. However, a recent study that used multiplanar magnetic resonance (MR) imaging revealed that the use of these radiographic landmarks to define the SVC/atrial junction is flawed. Aslamy and colleagues (12) used MR imaging to evaluate the anatomy of the SVC in 42 patients. In this study, the median length of the SVC was 6.8 cm (range, 4.4–10.0 cm). Importantly, the intersection of the SVC with the right superior heart border was not a reliable radiographic landmark for the SVC/atrial junction. In 38% of patients, the superior right heart border was created by the lateral border of the left atrium, not the right atrium. In these patients, the true anatomic SVC/atrial junction was located a median distance of 1.0 cm (range, 0.5–4.5 cm) inferior (caudal) to the right superior heart border. Therefore, a catheter tip positioned within the cardiac silhouette would appear to lie within the upper right atrium but may actually be located in the distal SVC above the SVC/atrial junction.

As described by Aslamy et al (12) and Rutherford et al (15), the most reliable radiographic landmark to define the borders of the SVC is the right tracheobronchial angle. This angle is created as the right main bronchus bifurcates from the trachea. The superior (cephalad) border of the SVC is always superior to the right tracheobronchial angle. Aslamy et al (12) reported that the median distance from the origin of the SVC to the right tracheobronchial angle was 1.5 cm (range, 0.1–3.8 cm). In addition, the right tracheobronchial angle was at least 2.9 cm above the SVC/atrial junction. The median distance from the right tracheobronchial angle to the SVC/atrial junction was 4.9 cm (range, 2.9–6.8 cm). Therefore, a catheter tip positioned 3 cm below the right tracheobronchial angle would always be within the SVC. However, this important information regarding the use of the right tracheobronchial angle as a radiographic

landmark to define the boundaries of the SVC is rarely used in clinical practice.

Rapid movement of a catheter tip can also lead to misinterpretation of tip position on a chest radiograph. Singh and colleagues (16) evaluated 352 pediatric chest radiographs and reported that catheter tip movement caused blurring of the image in 10 radiographs (3.5%). The majority of the catheters that exhibited this phenomenon were umbilical vein catheters with their tips positioned within the right atrium. Poor imaging of the catheter tip led to a major misinterpretation of tip position in 20%–25% of these patients. Although this phenomenon is likely accentuated by the rapid heart rate in pediatric patients, catheter motion can also cause a blurring artifact, and a potential for misinterpretation, on chest radiographs in adult patients.

In summary, the assessment of catheter tip position with use of a chest radiograph is often inaccurate and subject to interobserver variability. The best radiographic landmark for catheter tip positioning is the right tracheobronchial angle. An understanding of the anatomic relationships between the right tracheobronchial angle and the borders of the SVC are necessary for an accurate assessment of catheter tip position with chest radiography.

CATHETER TIP MOVEMENT

A critical concept to understand is that there are significant changes in the position of a catheter tip when the patient changes position. The direction and degree of catheter tip movement is dependent on several variables, including the type of catheter, insertion site, and body habitus of the patient.

The final position of the tip of a PICC is dependent on the specific insertion site and the position of the patient's arm. A PICC is often inserted with the arm abducted 90° from the patient's body with the head turned toward the ipsilateral side and the chin touching the chest (17–19). This position straightens the curve in the subclavian vein and decreases the angle between the subclavian and internal jugular veins. However, clinical studies have demonstrated that there is significant movement of the catheter tip when the patient changes the posi-

tion of the arm (18,20). If the PICC is inserted with the arm abducted, the tip of the catheter will move lower (caudal) when the arm is moved to the patient's side (adducted). In the majority of patients, the tip of the PICC will move at least 2 cm lower, toward the right atrium. Clinical studies have also reported that a PICC placed in the right arm will move more than one placed in the left arm, and those placed in the basilic vein will move more than those in the cephalic vein (18,20). Therefore, if a PICC is inserted with the arm abducted and the catheter tip is positioned in the lower SVC as recommended by the National Association of Vascular Access Networks guidelines, the catheter tip will move into the upper right atrium when the arm is lowered (adducted). Alternatively, if the PICC is inserted with the patient's arm at his/her side (adducted), the tip of the catheter will move upward into the upper SVC or brachiocephalic vein when the arm is raised (abducted).

There are two relevant anatomic changes that must be considered when inserting larger-diameter catheters into the subclavian or internal jugular veins. In the supine position, the mediastinal structures, including the central veins, are compressed by the abdominal contents (21). When the patient moves to an upright position, the abdominal contents descend, the central veins lengthen, and the right atrium expands. Because the external segment of a catheter is fixed (sutured) to the outside surface of the patient's body, this lengthening of the mediastinal structures will cause a relative change in the position of the catheter tip with respect to the SVC and right atrium. When a patient moves from a supine position to a sitting position, the catheter tip moves upward (cephalad) in relation to the right atrium. In addition, there is another anatomic force that influences the final position of cuffed catheters and subcutaneous ports. These vascular access devices are tunneled or implanted within the anterior chest wall while the patient is in a supine position. When the patient moves to an upright position, the anterior chest wall will shift inferiorly because of gravity (22,23). The external segment of the catheter that is fixed within the chest wall will be pulled downward, causing the intra-

vascular segment of the catheter to be pulled upward (cephalad). A tunneled catheter tip that is initially positioned into the right atrium will often retract upward into the lower SVC when the patient moves to a sitting or standing position. Kowalski et al (22) reported that the average upward movement of the catheter tip was 3.2 cm. This phenomenon is most pronounced in female patients with substantial breast tissue and in overweight patients of either sex. Several investigators have also reported that larger-diameter catheters move more than smaller-diameter catheters and that catheters inserted into the subclavian vein will retract more than those in the internal jugular vein (21,22).

As described earlier, the tip of a central venous catheter is not in a fixed location but will exhibit a range of motion as the patient changes body positions. A correctly placed catheter tip will likely be one that undergoes a range of movement (2–3 cm) between the SVC and the upper right atrium. Most importantly, it is imperative that the vascular access practitioner understand the direction and degree of anatomic forces that can act to move a catheter tip.

CATHETER PERFORMANCE

The recommendations of the K/DOQI guidelines are based on the superior performance of a hemodialysis catheter when the tip is positioned into the upper right atrium (6). A hemodialysis catheter is the Ferrari of central venous catheters. A typical hemodialysis treatment requires a catheter blood flow rate of 450 mL/min and the ability to sustain this high flow for 3–4 hours. Positioning the tip of a hemodialysis catheter into the SVC or higher can limit its ability to achieve this high level of performance (24). The catheter tip may “suck” against the adjacent vascular wall when aspiration is applied. This can also occur if the catheter tip is positioned too far within the right atrium.

Several clinical studies have demonstrated that the performance and durability of hemodialysis catheters is improved if the tip is positioned within the right atrium (25–28). McCarthy et al reported the duration of survival of 475 tunneled hemodialysis catheters (25). The mean survival of

218 catheters positioned within the right atrium was 245 days. The 117 catheters positioned at the SVC/right atrial junction had a mean survival of 116 days. Eighty-eight catheters positioned with tips in the SVC had a mean survival of 100 days and the 12 catheters with tips in the brachiocephalic vein survived for only 12 days.

Mandolfo et al (26) evaluated the performance of tunneled hemodialysis catheters in 57 patients and reported that catheters with tips positioned in the right atrium had significantly higher blood flow than those with tips positioned in the SVC or inferior vena cava. Similarly, Petersen et al (27) reviewed a series of 141 patients with ports or large-diameter tunneled catheters and reported that catheter malfunction was minimized when the catheter tip was located within the right atrium. These investigators found that there was a significant increase in catheter malfunction when the catheter tip was located more than 4 cm superior to the SVC/atrial junction.

These studies suggest that the performance of high-flow catheters such as hemodialysis and pheresis catheters can be improved by positioning the catheter tip within the upper right atrium. However, the majority of patients who require central venous catheters do not need such high-performance capabilities. A catheter used for more routine vascular access indications will usually work well when positioned within the lower segment of the SVC.

COMPLICATIONS ATTRIBUTED TO CATHETER TIP POSITION

Thrombosis

It is difficult to confidently ascertain the relationship between catheter tip position and thrombosis. Some physicians advocate the placement of a catheter tip into the right atrium to decrease thrombosis, whereas others are adamantly opposed to this position and believe that a catheter tip placed within the right atrium is predisposed to thrombosis.

A catheter inserted into a vein will be recognized as a foreign object and quickly covered with fibrin and plasma proteins (29). This is often fol-

lowed by the deposition and aggregation of platelets, the building blocks of thrombus, onto the surface of the catheter. Although the deposition of plasma proteins and platelets onto the surface of a catheter is an expected event, in certain situations, this process may further evolve into catheter thrombosis or fibrin sheath formation.

Vascular injury is considered a primary initiating event for catheter-related thrombosis (30). Vascular damage may occur early at the time of catheter insertion, or the injury may be progressive, as in the setting of a malpositioned catheter tip.

Early thrombosis may result from an acute venous injury sustained at the time of catheter insertion. Standard venous access techniques with the use of vascular dilators or a large-caliber introducer sheath can cause significant damage to the venous entry site. In addition, when using a left-sided approach, the endoluminal wall of the left brachiocephalic vein can be damaged when a stiff dilator or introducer sheath is advanced into the SVC. Ducatman and colleagues (29) performed an autopsy study of 141 patients with central venous catheters and reported that 32% had pericatheter thrombus in the brachiocephalic veins or SVC within 2 weeks after catheter insertion.

A catheter tip positioned against a vascular wall may become a source of persistent irritation (30). This may lead to denudation of the vascular endothelium, creating a potential nidus for thrombus formation. In an autopsy study of 24 patients who had Swan-Ganz catheters, Ford and Manley (31) reported that 50% of patients had evidence of endocardial injury when the catheter had been in place for greater than 48 hours. The endocardial injuries included subendocardial hemorrhage, mural ecchymosis, and thrombotic vegetations.

Alternatively, catheter-induced thrombosis may be caused by a subacute or chronic injury. Reed et al (32) reported the autopsy findings in 59 patients with leukemia who had Hickman catheters. Ten patients (17%) had mural thrombus in the SVC or right atrium. Eight of these patients had a catheter in place for greater than 150 days. Interestingly, no thrombus was found in seven patients who had Hick-

man catheters in place for more than 1 year.

In another study, Kung and colleagues (33) reported a series of 10 patients with long-term (tunneled) hemodialysis catheters who had right atrial thrombus diagnosed by transesophageal echocardiography. The catheters were positioned at the junction of the SVC and right atrium. When the right atrial thrombus was discovered, the mean length of time (\pm SD) that the catheter had been in place was 13 weeks \pm 12.8. Of important note, in this group of 10 patients, the average number of previous catheters implanted was 3.4 ± 2.7 per patient before identification of the right atrial thrombus. The etiology of the right atrial thrombus may have been from the chronic duration of catheter use or repeated vascular trauma from multiple catheter insertions. As noted by the authors of this study, placement of the catheter tip at the SVC/right atrial junction did not prevent the formation of right atrial thrombus (33).

Vascular injury with subsequent thrombosis has been reported to occur more frequently in patients who have a left-sided catheter (34,35). When inserted from a left-sided approach, the catheter tip will turn from the left brachiocephalic vein into the SVC and will lie against the right lateral wall of the SVC. The catheter must be of sufficient length to completely turn this corner to position the catheter tip into the lower segment of the SVC. However, if the catheter is too short, the catheter tip will poke into the right lateral wall of the SVC. Continual movement of the catheter tip caused by cardiac pulsations or patient movement may incite progressive damage to the vascular wall and increase the likelihood of thrombosis. Puel and colleagues (34) evaluated the association between catheter tip position and subsequent thrombosis in 379 patients who received a port for chemotherapy. Ten patients (2.6%) had symptomatic venous thrombosis documented by contrast material-enhanced venography, nine of whom had thrombosis of the SVC and one of whom had thrombosis of the left subclavian vein. An analysis of the data revealed that there was a 28.6% incidence of thrombosis if the catheter was inserted from the left side and the tip was positioned in the upper half of the SVC. There was a 3% inci-

dence of thrombosis when the catheter was inserted from the right side and the tip was positioned in the upper SVC. However, if the catheter tip was positioned in the lower SVC or upper right atrium, the incidence of thrombosis was 1.5% when the catheter was inserted from the right side. There were no episodes of thrombosis if the catheter was placed from the left side and the tip was positioned in the lower SVC or upper right atrium (34).

Another important factor to consider is the intended use of the catheter. The infusion of vesicant (caustic) solutions may irritate or damage the endothelium adjacent to the catheter tip (35,36). Pithie and colleagues (36) retrospectively reviewed a series of 45 patients who received a dextrose solution as parenteral nutrition. Twelve patients (26.7%) developed venous thrombosis and all these patients had their catheter tip positioned within the SVC. However, 16 other patients had catheter tips within the right atrium and none developed venous thrombosis (36).

Proponents of positioning a catheter tip into the right atrium argue that positioning the tip within a large chamber (ie, right atrium) will prevent it from contacting the vascular wall and thereby decrease the risk of endothelial injury. In addition, the substantial blood flow within the right atrium will prevent the accumulation of thrombus on the catheter tip. In addition, if the catheter is used for the infusion of caustic substances, the injurious effect will be minimized by the tremendous blood flow in the right atrium.

However, those practitioners with an opposing viewpoint will argue that there is a higher incidence of thrombosis when the catheter tip is positioned within the right atrium. Gilon and colleagues (37) used transesophageal echocardiography to evaluate central venous catheters in 55 patients. Of 13 patients who had the catheter tip extending into the right atrium, 46% developed pericatheter thrombus. Patients who had the catheter tip positioned in the distal SVC or at the SVC-right atrial junction had no evidence of catheter thrombus. These investigators speculate that there is an area of stagnation in blood flow within the right atrium and placement of a catheter tip into this area will potentiate thrombus

formation (37). However, advocates of right atrial positioning would argue that a 46% incidence of catheter-related thrombosis is exceedingly high and additional factors may have been responsible for this problem. Cohn et al (38) also used transesophageal echocardiography to evaluate catheter-induced right atrial thrombus in 19 patients. Although the position of the catheter tip was not described, freely mobile pedunculated masses were found in the SVC in nine patients, on the right atrial wall in three patients, and near the tricuspid valve in three patients. In addition, sessile masses were identified in the SVC in four patients and along the right atrial wall in three patients. These findings would suggest that a central venous catheter may cause vascular injury, with subsequent thrombosis, anywhere along its intravascular course.

Catheter-induced thrombus within the SVC or right atrium may become clinically significant long after the catheter has been removed. Kingdon and colleagues (39) described three patients who had symptomatic pulmonary emboli occurring months to years after removal of a hemodialysis catheter. Echocardiography performed at the time of the patient's acute symptoms revealed chronic thrombus within the right atrium. The etiology of this thrombus was attributed to positioning the tip of the previous hemodialysis catheter within the right atrium.

A variety of materials have been used for the construction of central venous catheters. Certain materials such as Teflon or polyethylene have been reported to be particularly thrombogenic, whereas silicone catheters are biologically inert and more resistant to thrombosis (40–42). Polyurethane, a commonly used material for catheter construction, includes a broad class of thermoplastic polymers that have an intermediate level of thrombogenicity (43). Yet, these important concepts regarding the thrombogenicity of catheter materials have not been addressed in much of the scientific literature pertaining to catheter tip position and subsequent thrombosis. Several investigators even failed to describe the type of catheters used in their studies. The lack of such important information affects the interpretation and credibility of the reported results.

A similar problem exists with clinical studies of central venous catheters in patients with cancer. Patients with certain types of solid tumors (eg, pancreatic, renal cell) are predisposed to vascular thrombosis (Trousseau syndrome). Therefore, the incidence of catheter-related thrombosis occurring in patients with cancer is not necessarily comparable to the thrombosis rate in patients who do not have cancer. In addition, Haire and colleagues (44) reported that catheter-induced thrombosis may be related to the patient's platelet count at the time of catheter placement. Patients with platelet counts less than 150,000/mL were less prone to thrombosis compared to patients with platelet counts greater than 150,000/mL.

Clearly, there are numerous variables that have been shown to affect the incidence of catheter-induced thrombosis. Unfortunately, these variables are frequently not described in clinical studies of catheter-induced thrombosis. Therefore, a critical analysis of the scientific data on this subject is made even more difficult.

In summary, the relationship between catheter tip position and subsequent thrombosis is complex and multifactorial. The primary initiating event for catheter-related thrombosis is an injury to the vascular wall. This injury may occur at the time of catheter insertion or may be caused by a malpositioned catheter tip causing chronic irritation. Appropriate positioning of the entire catheter can minimize injuries caused by the catheter tip. To prevent endoluminal injury, the course of the catheter should parallel the wall of the SVC and the tip of the catheter should move freely within the vascular lumen.

Catheter-induced Perforation

A vascular or cardiac perforation is the most feared and most deadly complication related to central venous catheters. Prevention of this complication is a fundamental goal of the FDA and the nursing societies that oppose the placement of catheter tips into the right atrium. However, again, this is a complex subject. A review of the literature suggests that vascular erosion or perforation can occur with the catheter tip in any location. As stated by Rutherford, "clear epidemiologic evidence

for the general contention that one position is safer than another is in fact lacking" (15).

A common problem found in the literature on this subject is a failure to distinctly separate complications that occur during catheter insertion procedures from those caused by malposition of the catheter tip or placement of the tip into the right atrium.

Robinson and colleagues (10) retrospectively reviewed the medical records of patients at their institution who had a catheter-related perforation of a major vessel. In this series of approximately 4,000 catheter insertion procedures, 10 patients had a vascular perforation, an incidence of 0.25%. These investigators reported that operator error was the primary cause of vascular perforation. More specifically, the injury was caused by kinking of the guide wire followed by forcing the vessel dilator or peel-away sheath into the central vein. The initial error, kinking of the guide wire, was the result of the operator's failure to firmly hold and stabilize the guide wire while advancing the vessel dilator. In all these patients, the vascular perforation was diagnosed within 24 hours, most often within 2–4 hours after completion of the procedure (10).

Although catheter-related perforations are now rare, this complication continues to occur. In 1991, Kalen et al (45) described four patients who died from catheter-induced cardiac perforation when silicone catheters were positioned within the right atrium. Based on their experiences, these investigators strongly advocated positioning the catheter tip in the SVC. However, a careful analysis of their data may suggest an alternative scenario. All four patients died of cardiac tamponade soon after catheter insertion; one patient died within 2 hours, one within 8 hours, another within 12 hours, and the fourth 24 hours after catheter insertion. Imaging guidance was not used during any of these catheter insertion procedures. Therefore, the lack of imaging guidance, combined with the rapid progression to cardiac tamponade after catheter insertion, suggests that the fatal injury may have occurred during the insertion procedure and was not necessarily caused by positioning the catheter tip into the right atrium. Early perforation is thought to result from opera-

tor error during the insertion procedure whereas late perforations may be caused by vascular injury from the catheter tip (46).

Left-sided catheters have been reported to have a higher incidence of vascular perforation. In a retrospective review of more than 1,000 catheter placements, Mukau et al (41) reported four patients with perforation of the SVC. All four had left-sided catheters and the average time interval to clinical symptoms was 5 days. Tocino and Watanabe (47) described nine catheter-related perforations of the SVC. Eight of these nine patients had left-sided catheters. Similarly, Duntley and colleagues (48) reported a series of eight patients who had catheter-related vascular perforations. Seven of these catheters were inserted from the left side, and six of these patients had catheter tips that were described as "abutting the right lateral wall of the superior vena cava." In this group of eight patients, the clinical manifestations of vascular perforation became evident 2.9 days \pm 0.8 after catheter insertion.

As previously described, catheters inserted from the left side must turn a 90° corner to enter the SVC. If the catheter length is short, the tip will be positioned against the lateral wall of the SVC. Persistent movement of the catheter tip caused by cardiac pulsations or patient movement can lead to erosion and perforation through the vascular wall. Therefore, positioning the catheter tip in the lower segment of the SVC may be safer because the catheter will tend to lie parallel to the vessel wall (49).

The majority of vascular or cardiac perforations related to central venous catheters were reported in the 1970s and 1980s. This is a likely result of the use of rigid catheters and the lack of imaging guidance during insertion procedures (50). Vascular perforations have been attributed to the use of stiff plastic material such as polyvinyl chloride and polyethylene for catheter construction (51–53). The use of softer catheter materials such as silicone and polyurethane is thought to have substantially decreased the likelihood of this complication (24). However, Duntley et al (48) reported a series of eight patients who developed catheter-related vascular erosions with catheters constructed of polyurethane.

Vascular damage and subsequent perforation can occur with any catheter if the distal tip is positioned against a vascular wall.

Ideally, the catheter tip should be located in the center of the vascular lumen. This position is best achieved with the right internal jugular vein used as the catheter insertion site. A catheter inserted from the right internal jugular vein will have a straight course into the SVC or upper right atrium, thereby allowing free movement of the catheter tip. However, as described earlier, optimal positioning of a catheter tip into the SVC is more difficult when using a left-sided approach.

Catheter-induced Cardiac Arrhythmia

Positioning a catheter tip into the right atrium is thought to increase the likelihood of cardiac arrhythmias. Despite this persistent concern, there is minimal evidence to suggest that this is a significant clinical problem (21,54).

The most common cause of a catheter-related arrhythmia is the physician's inattention to the position of a guide wire or catheter tip during catheter insertion or exchange procedures (55,56). These arrhythmias are typically benign and can be resolved by withdrawing the offending guide wire or repositioning the catheter tip. The use of fluoroscopic imaging during catheter insertion procedures, combined with cardiac monitoring, has substantially reduced the incidence of intraprocedural arrhythmias (57).

Delayed (postprocedural) cardiac arrhythmias are rare. In a series of 963 PICC insertion procedures, Ng and colleagues (54) described four patients (0.4%) who had delayed onset of palpitations, premature ventricular contractions, or ventricular tachycardia. All these PICC insertion procedures were performed without imaging guidance.

Catheter-induced arrhythmias rarely cause significant morbidity or mortality (58). However, in a series of 300 patients who underwent surgical insertion of 329 subcutaneous infusion ports, Brothers et al (59) reported a 0.9% incidence of serious arrhythmias requiring intervention. Again, all these catheters were inserted without imaging guidance.

A catheter tip positioned within the

SVC may evoke an arrhythmia when the patient changes body position. Bivins and Callahan (58) described two patients with peripherally inserted central catheters who developed ventricular tachycardia when they were turned to the left lateral decubitus position. Both patients had chest radiographs confirming the catheter tip position within the SVC. However, the change in patient positioning caused the catheter tip to extend into the right atrium and elicit the arrhythmia. Both patients returned to normal sinus rhythm when the tip of the PICC catheter was withdrawn into the upper SVC.

In summary, the most common cause of a catheter-induced cardiac arrhythmia is failure to watch the guide wire or catheter tip during the insertion procedure. A catheter tip that has been positioned at the SVC/right atrial junction will rarely evoke a clinically significant arrhythmia.

CONCLUSION

More than 800,000 central venous catheters were placed by physicians in 1999 and the majority of these catheters were inserted by surgeons and anesthesiologists without imaging guidance (60). Several studies have reported that 10%–30% of catheters placed without imaging guidance have a malpositioned catheter tip or a catheter tip in the right atrium (12,15,49). Therefore, it is likely that thousands of central venous catheters are malpositioned each year. However, the discrepancy between the number of central venous catheters that are placed and the number of reported complications suggests that serious complications are rare (39).

Optimal positioning of a catheter tip is a complex subject that will continue to evolve. The scientific literature has thus far failed to provide sufficient evidence to indisputably support or condemn the placement of a catheter tip into the right atrium.

Determining the best position for a catheter tip requires an understanding of numerous clinical variables including catheter type, insertion site, the patient's body habitus, and the intended use of the catheter. The majority of central venous catheters used for routine applications should be positioned with the distal tip in the SVC. However, to achieve optimal perfor-

mance of a hemodialysis or pheresis catheter, it may be necessary to position the tip within the upper right atrium.

When viewing a standard chest radiograph, the traditional methods for determining the position of a catheter tip are imprecise and can lead to misinterpretation. The right tracheobronchial angle is the best radiographic landmark to delineate the borders of the SVC and the SVC/atrial junction. It is also important to understand that, in the majority of patients, a catheter tip will exhibit a range of movement extending 2–3 cm. A catheter tip that is appropriately positioned within the inferior (caudal) segment of the SVC will likely move in and out of the upper right atrium with patient movement. The catheter insertion site and the patient's body habitus are important variables for determining the magnitude of catheter tip movement.

The most feared catheter-related complications, such as vascular perforation and cardiac arrhythmias, are rare. Importantly, these complications are often caused by physician errors during catheter insertion procedures. Of note, the incidence of vascular injuries is increased with left-sided catheters or if the catheter tip is abutting a vascular wall. Therefore, the preferential insertion site is the right internal jugular vein, and fluoroscopy should be used to visualize all endovascular manipulations during the catheter insertion procedure.

It is imperative that nurses and physicians continue to discuss vascular access-related issues in local and national forums. A cooperative, multi-specialty work group consisting of experts from nursing, radiology, surgical specialties, and federal regulatory agencies should be established to create an evidence-based consensus document to address vascular access-related issues. Such a document, similarly to the K/DOQI Guidelines, could provide nurses and physicians with information to construct local institutional protocols and consistent clinical practices.

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