Radiologic Interpretation of Central Venous Catheter Placement

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Abstract: When used in veterinary medicine, central venous catheters are typically inserted through the external jugular vein, with their caudal extension within the cranial vena cava. Radiographic or fluoroscopic guidance is recommended to assist in correctly placing these catheters. This article provides radiologic examples of common central venous catheter malpositions and complications.

Central venous catheterization is occasionally performed in referral and emergency veterinary hospitals. The risks associated with central venous catheter placement are normally offset by the benefits, such as enabling fluid administration at rapid rates, administration of irritant or hyperosmolar fluids such as total parenteral nutrition, assessment of central venous pressure (CVP), and frequent blood sample collection. Central venous catheter malposition has been reported in up to 14% of human patients, even when the catheter was inserted by an experienced clinician. In people, central venous catheter malposition has been reported to produce inaccurate CVP readings (brachiocephalic system), lead to a higher risk of thrombus formation and vessel occlusion (subclavian vein position, azigos vein), be associated with a relatively high risk of vascular perforation (azygos vein), and potentially be a source of pain. Accidental or intentional placement of the central venous catheter into the right atrium carries a risk of arrhythmia, atrial perforation, and life-threatening tamponade; however, large-bore, double-lumen central venous catheters are commonly placed and maintained satisfactorily in the right atrium for extended periods of extracorporeal circulation (e.g., during dialysis) in both human and veterinary patients.

Central venous catheters can be grouped into short-term and long-term catheters. The latter are seldom used in veterinary medicine. Short-term catheters can generally be used for up to 3 weeks when handled carefully and aseptically.

In small animal veterinary patients, central venous catheters are typically inserted through the external jugular vein, with their caudal extension within the cranial vena cava. Less conventional sites for venous access have been described, such as the lateral and medial saphenous veins, with the tip of the catheter being positioned in the caudal vena cava. The cephalic vein may also be used, with the catheter tip placed in the cranial vena cava; however, catheter insertion past the elbow can prove challenging. Correct central venous catheter placement is not significantly improved when using an electrocardiography-guided technique compared with the traditional external landmark technique; therefore, fluoroscopic or radiographic guidance is recommended for anything but short-term catheterization and in all cases requiring hemodynamic monitoring, high infusion rates, or administration of cytotoxic or osmotically active drugs. Diagnostic imaging may also help explain the cause of catheter dysfunction.

Correct Catheter Position
The ideal position for the tip of a jugular central venous catheter is caudal to the first rib and cranial to the right atrium (BOX 1). Visualization of the catheter tip outside of these landmarks could indicate malposition, such as left atrial, subclavian, or brachiocephalic positions. Venous access should be confirmed by fluoroscopic or radiographic imaging before placing the catheter tip outside these landmarks.

Key Points
- Fluoroscopic or radiologic guidance of central venous catheter placement should be done in every single case requiring hemodynamic monitoring, high infusion rates, or administration of cytotoxic or osmotically active drugs.
- Aspiration of blood from the catheter in no way confirms adequate placement.
- Except for hemodialysis, the catheter tip is ideally positioned between the first rib and cranial heart border, superimposed to the cranial vena cava on the lateral view. Radiographic signs of vascular perforation may be subtle or absent; if the catheter has traversed a great vein, bleeding or other problems may only become evident on catheter withdrawal.

Dr. Francey discloses that he has received honoraria from Hill’s Pet Nutrition, Royal Canin France, Vétiquinol, and Virbac S.A.
should prompt immediate repositioning. It should be remembered that the sharp soft tissue/lung interface cranial to the cardiac silhouette, often incorrectly referred to as the ventral border of the cranial vena cava, represents the cranial vena cava, on which various structures may be superimposed.

Although a lateral view of the caudal cervical area and thorax may be sufficient for radiologic central venous catheter placement guidance in many cases, two orthogonal radiographic views are necessary to confirm that the tip of the catheter is in the correct location. Injection of iodinated contrast medium into the central venous catheter can also help ascertain intravenous placement and location. At our institution, a small bolus of 2 to 3 mL of noniodinated contrast medium (300 mg iodine/mL), a bit more than required to fill the catheter, is injected rapidly and immediately flushed. Usual doses for nonselective angiography (400 to 440 mg iodine/kg) are ample. We prefer using fluoroscopy at 2 to 4 images/second; however, standard radiography during injection is satisfactory in most cases.

Ability or ease of blood aspiration from a central venous catheter in no way guarantees its correct placement.

Below are radiographic examples of several common catheter malpositions. Other examples of malposition (not depicted here) include curling of the catheter in the right atrium and insertion into the right ventricle.

**Common Malpositions**

**Internal Thoracic Vein Catheterization**

Whereas cats have paired internal thoracic veins, in dogs, the internal thoracic vein may be paired or unpaired, and either the single or the right internal thoracic vein terminates at the ventral surface of the cranial vena cava. If present, the left internal thoracic vein merges with the left brachiocephalic vein. The internal thoracic vein collects blood from vessels including the mediastinal, intercostal, and musculophrenic veins and is the only large intrathoracic vein cranioventral to the heart. The J-shaped end of the catheter guide wire, used in both patients depicted here, is designed to reduce the risk of endothelial injury in people. Some believe this curve may facilitate the insertion of the central venous catheter into smaller vessels. Patency of the central venous system should not be considered sufficient evidence of adequate placement.

**Box 1. Radiologic Interpretation Paradigm for a Central Venous Catheter in the Cranial Vena Cava**

The following radiographic findings (FIGURE A) are indicative of correct central venous catheter placement:

- The central venous catheter is superimposed on the cranial vena cava on all views.
- The tip of the central line lies between the first rib and the cranial border of the cardiac silhouette.
- The cranial border of the heart can be clearly delineated from the pericardial fat. The soft-tissue/lung interface cranial to the cardiac silhouette is sharply delineated.
- Cranial mediastinal width is normal:
  - Dogs: less than twice the width of the spine on VD/DV views
  - Cats: equal or less than the width of the spine on VD/DV views
- No evidence of pleural effusion is seen, unless present before central venous catheter placement.
- Absence of pneumothorax, unless present before catheter placement.

**Figure A.** Normal course and position of a central venous catheter in an Irish setter with septic peritonitis secondary to intestinal perforation. The tip of the catheter is at the level of the second rib (white arrow), superimposed with the soft tissues dorsal to the lung interface, cranial to the cardiac silhouette. The cardiac silhouette is sharply delineated. An endotracheal tube is seen at the edge of the image, ventral to C5.

**Figure 1.** Inadvertent internal thoracic vein cannulation. Lateral thoracic radiograph of a 7-kg Chinese crested dog treated for severe bite wounds. After a normal course along the deep cervical structures, the 7-Fr double-lumen catheter (white arrow) terminates ventral to the cranial vena cava, its tip oriented ventrally. Detail
in the cranial mediastinum is normal, and the soft-tissue/lung interface cranial to the cardiac silhouette is sharply delineated (black arrowhead), suggesting that perforation of the vena cava and subsequent mediastinal hemorrhage have not occurred. Blood was easily aspirated from both ports.

**Figure 2.** Same dog as in Figure 1. Contrast medium injected through the catheter flows back dorsally into the cranial vena cava and into the right heart. Extravasation is not observed. The severity of the patient's wounds and fractures precluded a change in position for a ventrodorsal view, and a horizontal-beam radiograph could not easily be performed in this radiographic suite. The contrast study was performed for educational purposes. This position does not fulfill any of the aims of a central venous catheter: CVP measurements would likely be skewed, a risk of wall irritation with hyperosmolar drug administration exists, restricted fluid administration rates and vascular congestion may occur, and blood sampling would be similar to that of a peripheral vein. The catheter was immediately repositioned.

**Figure 3.** Cannulation of the internal thoracic vein in a different dog. The catheter extends far ventral to the cardiac silhouette (arrows). Blood could be drawn from the catheter.

**Azygos Vein Catheterization**

The azygos vein joins the cranial vena cava at its termination in the right atrium, at the level of the right third intercostal space.

**Figure 4.** Aberrant catheterization of the azygos vein. Lateral right thoracic radiograph of a 16-kg standard schnauzer treated for leptospirosis and associated pulmonary hemorrhage. The central venous catheter (11.5 Fr, 20 cm, double lumen) is seen bifurcating dorsally at the level of the third thoracic vertebra before reaching the heart. An endotracheal tube is inserted to the level of C6 (black arrowhead), and an esophageal feeding tube (white arrow) can be seen up to the level of T7.

**Figure 5.** Same patient as Figure 4. Aberrant catheterization of the azygos vein. On the ventrodorsal projection, the catheter deviates toward midline.

**Caudal Vena Cava Catheterization**

With the exception of hemodialysis catheters, central catheters in or below the right atrium should be pulled back immediately in
an effort to prevent wall erosion or perforation, arrhythmias, or eventual administration of chemical irritants to the liver or heart.

**Figure 6.** Extension of the central line into the caudal vena cava. Right lateral thoracic radiograph of a 2.3-kg female Chihuahua treated for immune-mediated hemolytic anemia. The catheter is superimposed with the course of the cranial vena cava and right atrium but continues caudally to the cardiac silhouette. The caudal vena cava itself cannot be delineated clearly on this projection, and although an orthogonal view would be ideal, the adequate mediastinal detail makes perforation unlikely. The catheter was repositioned.

**Perforation**
A rare but potentially lethal complication of central venous catheterization is the rupture of larger vessels or of the right atrium. Some patients rapidly develop massive mediastinal effusion, recognizable as mediastinal widening and opacification, as well as border effacement of the mediastinal structures. Ventrodorsal or dorsoventral radiographs are more sensitive for the presence of mediastinal fluid. In dogs, the normal width of the cranial mediastinum on a ventrodorsal or dorsoventral view should be less than twice the width of the spine at the same level. In cats, the cranial mediastinum should not extend beyond the width of the vertebral column. Obese animals can have significant mediastinal fat deposits that may make assessment of mediastinal width more challenging. Depending on the exact structures perforated, pleural effusion and pneumothorax may also develop. Some animals may show relatively subtle radiographic changes, particularly patients with tamponade secondary to right atrial or ventricular perforation when the pericardium remains intact.

**Figure 7.** Perforation of the cranial vena cava. Lateral thoracic radiograph of a heparinized, dialyzed, 5-year-old cat with acute azotemia secondary to ureteral obstruction. The course of the 7-Fr, 16-cm, double-lumen central catheter diverges ventrally. Blood could be aspirated from the proximal port of this catheter. A lobar sign, the demarcation between a normally inflated lung lobe and an adjacent lobe of increased opacity, is visible between the right middle and right caudal lung lobes (black arrowhead). The soft tissue-lung interface corresponding to the ventral cranial vena cava contour is well delineated (white arrowhead).

**Figure 8.** Same cat as in Figure 7. The tip of the catheter (black arrow) lies right lateral to the cardiac silhouette and right middle lung lobe. Atelectasis of the right middle lung lobe is present, corresponding to the lobar sign visible in Figure 7. This atelectasis was attributed to anesthesia, and no radiographic change other than the extracardiac position of the catheter suggests perforation. However, thoracic rotation prevents assessment of the cranial mediastinum. The catheter was repositioned over a guide wire. The cat survived, but was later euthanized because of the ureteral obstruction.

**Paravenous Location**
Paravenous placement of a central line not only causes diagnostic and therapeutic setbacks, but also allows extravasation of vesicant drugs, which may have serious consequences for the patient. Paravenous insertion or catheter dislodgment must be ruled out when blood return is absent or sluggish or when pain or swelling or blanching of the skin is noticed.

**Figure 9.** Paravenous catheter placement. Lateral view after catheterization of the jugular vein in a 12-year-old bichon frise
Radiologic Interpretation of Central Venous Catheter Placement

with hypoparathyroidism. The central line (white arrow) extends to the level of the cranial vena cava, but diverges slightly from the soft-tissue–lung interface cranially to the cardiac silhouette (black arrowhead), which suggests malposition.

**Figure 9.**

**Figure 10.** Same dog as in Figure 9. Previous paravenous injection of calcium gluconate through a cephalic catheter led to severe soft tissue swelling of the brachium (black arrows, superimposed with the cranial thorax), which progressed to skin necrosis. Reduced central line function was noticed. A small amount of contrast medium injected through the central catheter (white arrow) simply infiltrated the surrounding tissues. Further inspection revealed that the central catheter was adjacent to the cranial vena cava.

**Catheter-Related Fibrin Sheaths and Thrombosis**

Eventually, a protein layer approximately 100 nm thick and consisting of γ-globulins, albumin, and coagulation factors covers any intravascular catheter. Direct endothelial damage, either at the site of venous puncture or at the catheter tip, can initiate the development of a fibrin sheath on this protein layer in as little as 24 hours. In people, fibrin sheaths usually manifest as catheter dysfunction 1 to 2 weeks after placement, characterized by persistent withdrawal occlusion and the need for injection at higher pressures. Progressive fibrin sheath thickening eventually leads to catheter failure. Untreated fibrin sheaths may be colonized by bacteria and, even when sterile, may contribute to thrombus formation. The diagnosis of a fibrin sheath is usually made using fluoroscopic catheter contrast angiography, although ultrasonography or contrast-enhanced thoracic computed tomography (CT) may be used. Up to 40% of cases of central venous catheter dysfunction in people are due to catheter-related thrombosis. Thrombosis can lead to secondary venous stenosis and occlusion, as well as pulmonary thrombosis.

**Figure 11.** Transverse post-contrast CT image of a dog at the level of the second ribs. A long filling defect in the cranial vena cava (white arrow) indicates a thrombus at the junction with the dilated right internal thoracic vein (white arrowhead). Pleural effusion is present (*). This patient, which had been diagnosed with leptospirosis, developed severe peripheral phlebitis associated with a cephalic catheter. This resulted in colonization of a central venous catheter previously used for hemodialysis and progressed to sepsis. Three weeks after catheter removal, the dog presented with severe chylothorax. CT lymphangiography was unsuccessful; obstruction of the thoracic duct by thrombus was assumed but not visualized.

**Catheter Fracture**

Mechanical stress may lead to catheter breakage. The loose fragment carries a substantial risk of infection, pulmonary embolism, and atrial or ventricular myocardial damage. The standard of care in people is interventional radiologic removal of the fragment, and several veterinary specialty centers now offer this service through interventional radiology. Surgical retrieval has been advocated in very small patients.

**Conclusion**

Radiology plays a key role in the management of patients with central venous catheters. Adherence to strict hygiene protocols, systematic radiologic guidance, and confirmation of patency can drastically reduce complication rates.

**References**

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