Central Venous Catheter-Induced Cardiac Tamponade: A Preventable Complication

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The insertion of central venous catheters (CVC) is a common invasive procedure used for fluids or drug administration, hemodynamic monitoring, venous gas aspiration and hemodialysis. Correct initial positioning of the tip of the CVC may prevent early complications as well as those arising late. In the current issue of the *Journal*, Kim et al.[1] describe a method of estimating the correct initial CVC insertion depth to prevent fatal complications.

Complications associated with CVC are numerous and can be roughly classified as early (<24 hours after insertion) or late (>24 hours after insertion).[2] Early complications are usually of mechanical nature and are more likely to be fatal than are the late ones. Cardiac tamponade is a rare mechanical complication carrying 65%–100% mortality rate, by far a worse prognosis than that from extravasation in any other site.[2,3] It is caused by fluid accumulation in the pericardial cavity after cardiac or vena cava perforation. As an early complication, tamponade is caused by direct puncture of the wall by guidewires, dilators, or catheters. Even though perforation may occur during insertion, it may not become manifest for several minutes to hours later, depending on the rate of fluid accumulation in the pericardial cavity. Late perforation, on the other hand, is usually the result of the catheter eroding the wall, thus causing tissue necrosis and subsequent perforation.[2] The most frequent sites of perforation are the superior vena cava and right atrium or ventricle, even though other locations have been documented.[2] This devastating complication can be easily prevented by positioning CVC tips outside the pericardial reflection, thus preventing fluid extravasation into the pericardial cavity. Current U.S. Food and Drug Administration recommendations are that the CVC be placed such that it lies in the vessel outside the pericardium.[4]

Chest radiography (CXR) is by far the most important test to verify that the CVC is properly placed outside the pericardial reflection. When examining the radiograph, most practitioners look for already-existing pathologies such as pneumothorax and hemothorax, and for right ventricular catheter position. However, the CXR can offer additional information that may prevent future injuries. The visceral pericardium extends over the great vessels as far as 3 cm.[5] Therefore, to prevent cardiac tamponade, the CVC tip should be situated 2 to 3 cm above the cava–atrial junction.[5] Rutherford et al. showed that the most reliable radiographic landmark is the right tracheobronchial angle.[6] This angle is created as the right main bronchus bifurcates from the trachea. In a magnetic resonance imaging study, Aslamy et al.[7] demonstrated that the right tracheobronchial angle was always at least 2.9 cm above the cava–atrial junction; thus, it is the best and most consistent radiographic landmark for proper CVC tip position. Another clue is the "curved-tip sign," which appears when the catheter tip is embedded intramurally in the vena cava wall. In two thirds of patients suffering cardiac tamponade, the curved-tip sign was noticed significantly earlier than were other clinical or radiological signs.[8] Thus, the CXR can provide valuable insight into the position and orientation of the CVC.

Every medical service routinely performs CXR *immediately* after CVC insertion and before any clinical use. This is not the common practice in anesthesiology in which CXR is obtained postoperatively. A reliable way to predict the correct insertion depth—to reduce tamponade risk and prevent unnecessary adjustments—is therefore warranted. The average distance to the cava–atrial junction from the right internal jugular (RIJ) insertion site is 18 cm[9] and the pericardium extends 2 to 3 cm above.[10] Therefore the maximal allowable depth of an RIJ CVC should never be >15 cm for a patient of average height.[11] The "proper" insertion depth, at the very least, depends on the size of the patient (pediatric versus adult, short versus tall adult). Determination of a reasonable first guess at appropriate depth has been based on patient height, known as the *Peres formula*[12] or topographic external landmarks such as *manubrium-to-thyroid notch distance*.[11] However, these approximations all suffer from the tyranny of the average. What is important is an awareness of the range of depths, and where the tip actually is in a specific patient. In the current study by Kim et al.,[1] this point is very well illustrated, for which the depth of insertion varied in an SD (standard deviation) magnitude of 1 to 2 cm. This means that 90% of the population is expected to have up to 4 cm variability (2 SD).

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Multiorifice CVCs are used for venous gas aspiration (in case of gas embolism) and as dialysis access ports. These are the only 2 indications for which a CVC tip may be positioned in the right atrium. For gas aspiration, during procedures in which venous gas embolism is possible, only multiorifice catheters should be inserted. The single lumen CVC design, as well as its recommended tip location, renders it ineffective for gas aspiration and therefore should not be used for this indication.[13,14]

Many methods have been used to verify correct initial positioning of the CVC tip once it was inserted, yet none is failsafe. Free blood return from every port must be checked to confirm that the distal port is intravascular, even though intrapleural positioning might be missed in the case of ipsilateral hemothorax.[15] Manometry demonstrating respiratory fluctuations helps to exclude arterial cannulation, yet it cannot exclude pleural placement.[15] Insertion of a guidewire into the heart to provoke arrhythmias (thus identifying the proximity of the catheter to the right ventricle) can be dangerous, because this maneuver might itself cause perforation.[16]

In the current issue of the *Journal*, Kim et al.[1] are proposing another way to assure the correct initial insertion depth of a CVC tip on the basis of external measurements, i.e., patient-specific criteria. The evidence presented refutes a common practice that one depth is suitable for the entire population.[11,17] In fact, in the specific population that Kim et al. studied, the average depth of a CVC was 12 cm for the RIJ approach, in contrast to the 16.5 cm depth suggested elsewhere for all patients.[11,17] This finding might appear too shallow for the general population, yet the average height of the population in the study was 160 cm, further strengthening this point. Adopting the average depth cited byKim et al. as a guideline might provide a wider margin of safety because it was measured in a shorter stature population.

In a series of 25 reported CVC-induced cardiac tamponade complications by Collier et al., 20 patients died, 3 patients survived in a persistent vegetative state, and only 2 survived without neurological sequelae.[18] Although occurrence of cardiac tamponade may not be associated with obvious perforation or early cardiovascular compromise, improper positioning of the CVC within the pericardial region of the great vessels may ultimately result in perforation and tamponade hours after the insertion. Although Kim et al.[1] have rightly suggested that utilizing landmarks and measuring the correct depth for CVC insertion results in more accurate positioning, the amount of error inherent in this approximation is enough to warrant additional means of determining CVC positioning. With the specter of early and late cardiac tamponade looming over CVC insertion, it behooves us to use multiple modalities to accurately determine CVC positioning and to consider CXR as the "gold standard," an absolutely essential test immediately following CVC placement. Thus it is our recommendation to use all available modalities for prevention of harm:

1. Do not insert CVC unless clinically indicated.
2. Determine patient-specific, desired CVC tip depth by any external technique (such as manubrium-to-thyroid notch distance).
3. Do not advance RIJ CVC deeper than 15 cm.
4. Use manometry to exclude inadvertent arterial cannulation.
5. Ensure free blood return from all CVC ports.
6. Obtain CXR as soon as possible to determine the exact position of the CVC tip, in addition to ruling out pneumothorax or hemothorax.
7. Monitor central venous waveform to diagnose the disappearance of the waveform in a case of vessel perforation.
8. Instruct residents and intensive care unit nurses on the importance of normal central venous pressure waveform disappearance.
9. Whenever assuming care of a patient with a preexisting CVC, reconfirm positioning and functionality by means suggested in recommendations 5 to 7 above, and correct tip positioning if necessary. (Additional CXR should be obtained only if in the previous study the tip was not positioned correctly.)

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REFERENCES

1. Kim MC, Kim KK, Choi YK, Kim DS, Kwon MI, Sung KJ, Moon JY, Kang JM. An estimation of right- and left-sided central venous catheter insertion depth using measurement of surface landmarks along the course of central veins. Anesth Analg 2011;112:1371–4
2. Askegard-Giesmann JR, Caniano DA, Kenney BD. Rare but serious complications of central line insertion. Semin Pediatr Surg 2009;18:73–83
3. Friedman BA, Jurgeleit HC. Perforation of atrium by polyethylene CV catheter. JAMA 1968;203:1141–2
4. Cardiac Perforation and Tamponade: The Deadly Duo of Central Venous Catheters. FDA Patient Safety News: Show #1, February 2002
5. Shuster M, Naveh H, Pipenbrock S, Pabst R, Panning B. The carina as a landmark in central venous catheter placement. Br J Anaesth 2000;85:192–4
6. Rutherford JS, Merry AF, Occleshaw CJ. Depth of central venous catheterization: an audit of practice in a cardiac surgical unit. Anaesth Intensive Care 1994;22:267–71
7. Aslamy Z, Dewald CL, Heffner JE. MRI of central venous anatomy: implications for central venous catheter insertion. Chest 1998;114:820–6
8. Tocino IM, Watanabe A. Impending catheter perforation of superior vena cava- radiographic recognition. Am J Roentgenol 1986;146:487–90
9. Murray H. Procedures in the intensive care. In: Murray M. (Ed.) Critical Care Medicine: Perioperative Management. 2nd ed. Philadelphia, PA: Lippincot & Williams, 2002:107
10. Stonelake PA, Bodenham AR. The carina as a radiological landmark for central venous catheter tip. Br J Anaesth 2006;96:335–40
11. Ezri T, Weisenberg M, Sessler DI, Berkenstadt H, Elias S, Szmuk P, Serour F, Evron S. Correct depth of insertion of right internal jugular central venous catheters based on external landmarks: Avoiding the right atrium. J Cardiothorac Vasc Anesth 2007;21:497–501
12. Peres PW. Positioning central venous catheters—a prospective survey. Anaesth Intensive Care 1990;18:536–9
13. Schäfer ST, Lindemann J, Neumann A, Brendt P, Kaiser GM, Peters J. Cardiac air transit following venous air embolism and right ventricular air aspiration. Anaesthesia 2009 Jul;64:754–61

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14. Drummond JC. Neurosurgical anesthesia. In: Miller's Anesthesia. 6th ed. Philadelphia, PA: Churchill Livingstone Elsevier, 2010:2055–7
15. Brister NW, Barnette RE. Inter-pleural placement of central venous catheters. Chest 1992;101:1458–9
16. Sunder-Plassmann G, Muhm M, Drum W. Placement of central venous access catheters by overinsertion of guide wires: low complication rate in 1527 central venous access devices. Nephrol Dial Transpl 1966;11:911–2
17. McGee WT, Ackerman BL, Rouben LR, Prasad VM, Bandi V, Mallory DL. Accurate placement of central venous catheters: a prospective, randomized, multicenter trial. Crit Care Med 1993;21:1118–23
18. Collier PE, Blocker SH, Graff DM, Doyle P. Cardiac tamponade from central venous catheters. Am J Surg 1998;176:212–4

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