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CVC Removal: A Procedure Like Any Other

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The Case

A 27-year-old man with a history of Behçet disease and recurrent liver abscesses was admitted to the hospital for a prolonged intravenous antibiotic course for treatment of the abscesses. Due to difficult peripheral venous access, a right internal jugular central venous catheter (CVC) was placed. After completion of the antibiotic course, the CVC was removed and the patient was discharged 30 minutes later. He subsequently experienced acute onset of shortness of breath associated with a "whistling sound" from his neck. He re-presented to the emergency department with hypoxia and a significant Alveolar–arterial gradient, requiring 15 L high-flow oxygen to maintain his oxygen saturation. A tentative diagnosis of air embolism was made, and computed tomography of the chest did not reveal other abnormalities that would explain his hypoxia, such as pulmonary embolism, pneumonia, pulmonary edema, or pneumothorax. The patient had a brief stay in the intensive care unit and improved rapidly.

On review of the case, it was determined that the CVC had been removed while the patient was in an upright position, and that the removal site was not covered with an occlusive dressing. The physician who removed the CVC had completed the required central line training module a year earlier, which included one slide on proper removal technique. The physician was not aware that the hospital CVC removal protocol specified the use of a CVC removal kit, and that the kit was available on the ward. The kit contained instructions for the procedure and the appropriate materials, including the occlusive dressing.

The Commentary

Central venous catheters (CVC) provide two conditions necessary for air embolism formation: (i) direct connection between a source of air and the vascular system, and (ii) a pressure gradient that raises risk of this air entering the bloodstream. CVC-associated air embolism has an incidence of 1 in 47 to 1 in 3000 (1,2) and mortality rates from 23% (3) to 50%.(4) Because of the high mortality and the widespread use of CVCs, it is essential that health care providers inserting, handling, and removing CVCs are familiar with how air embolism occurs and how to prevent it.

Air introduced into the venous system travels to the right side of the heart and into the pulmonary vasculature. While small volumes of air entering the circulatory system can be absorbed by the body and may be asymptomatic, rapid introduction of air, particularly in high volumes, can lead to an accelerated rise in pulmonary artery pressures. The acute pulmonary hypertension puts strain on the right side of the heart, causing symptoms such as those exhibited by the patient in the current case study. In general, the closer to the heart air is introduced into the venous system, such as through a CVC, the smaller the volume of air is required to cause symptoms. The volume of intravenous air necessary to be fatal in adults is 200 to 300 mL, an amount that can enter the bloodstream in a matter of seconds through a CVC.(5) However, even a small venous air embolism can be fatal in patients with a patent foramen ovale (estimated to occur in 25% of the general population, often undiagnosed), as the air can pass immediately into the cerebral arterial circulation (causing a stroke) or the coronary circulation (causing a myocardial infarction), a process known as paradoxical embolization.(6)

Central venous pressure (CVP) is normally lower than atmospheric pressure in all blood vessels located above the heart, including the superior vena cava, where most CVCs terminate. This creates a pressure gradient that aids movement of air into the venous system through a CVC, or the tract left after CVC removal, if proper precautions are not taken. This gradient is increased in the upright position, as blood pools in the lower extremities, further lowering CVP. In fact, CVC removal while a patient is in an upright position, as described in this case, has been identified as the most frequently reported contributing factor for CVC-associated air embolism formation in an analysis of over 7 years of air embolism events submitted to the Pennsylvania Patient Safety Authority.(7)

Prevention of CVC-associated air embolism is achieved by eliminating the two conditions necessary for its formation: (i) physically blocking the direct connection between the air and the vascular system created by a CVC or the tract left after removal, and (ii) taking steps to increase CVP, thereby decreasing the pressure gradient that promotes air embolism formation.(5,8,9) The Table lists best practices to prevent air embolism formation during CVC removal.

The physician in this case committed a knowledge-based error.(10) Despite having completed the central line training module the year before, he demonstrated a lack of knowledge of the hospital's CVC removal protocol. The fact that the training "included one slide on proper removal technique" suggests that this education was insufficient. It is not mentioned whether this physician had experience in removing CVCs, but the fact that he was not familiar with the protocol or the CVC removal kit suggests inadequate experience, as well as a failure on the part of the hospital to assess his competency in performing the procedure. Lack of appreciation for CVC removal as a high-risk procedure is common among clinicians and hospitals. Historically, CVC insertion has received attention as a procedure with multiple serious potential risks, while CVC removal has not.(11) Based on this bias, CVC insertion has long been included in lists of procedural competencies required of resident physicians, while CVC removal has not.(12,13) Recently, CVC insertion technique has received renewed attention as part of infection prevention initiatives; however, steps to prevent air embolism are not stressed. When CVC removal is mentioned, instructions are often vague (i.e., "position patient correctly for procedure").(14)

CVC removal is a procedure, distinct from CVC insertion, with its own unique set of potential complications. Aside from air embolism formation, CVC removal carries other risks such as bleeding, catheter fracture, and embolism (discussed in a previous AHRQ WebM&M commentary), and dislodgement of thrombus from the CVC tip. Education for all health care personnel expected to perform the procedure should include a discussion of these potential complications, along with specific training in the techniques necessary to prevent their occurrence.(11) As with other procedural competencies, initial training through simulation is recommended. Health care personnel should be supervised in performing the procedure in clinical practice and assessed for competence.(12) Annual reassessment of competence has been suggested.(15)

The CVC removal kit described in this case is a good example of a system design solution to support safe patient care. However, as the case illustrates, the kit itself does not guarantee that the proper removal procedure will occur. A process change is needed to ensure that only health care professionals who have received adequate training, and who have been assessed as competent in performing the procedure, are permitted to remove CVCs.(15) The Infusion Nurses Society has established standards of practice for competency in CVC insertion, management, and removal "toward the goal of preventing air emboli."(9) The establishment of an infusion nurse team with responsibility and accountability for insertion and removal of CVCs is an example of a process change that has been effective in reducing CVC-associated complications in some hospitals.(16)

Take-Home Points

- CVC-associated air embolism is a preventable complication that can result in serious harm, including death. Increased awareness is needed that CVC removal is a high-risk procedure.
- Hospitals are advised to establish policies and procedures that contain specific air embolism prevention protocols for CVC insertion, management, and removal.
- CVC insertion and removal should only be performed by health care professionals who have received adequate training and who have been assessed as competent in performing the procedure.
- The importance of increasing CVP by avoiding the upright position during CVC removal must be stressed in CVC removal training.
- Establishment of a dedicated infusion team and use of a standardized CVC removal kit, including step-by-step instructions for performing the procedure and all necessary materials, are process improvements that may improve CVC removal technique and outcomes.

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Table

Table. Steps to Prevent Air Embolism During Central Venous Catheter (CVC) Removal

Step	Rationale	Discussion

1. Provide hydration to patients who are hypovolemic, prior to the procedure.	Increases central venous pressure (CVP)	Hydration may not be possible in patients unable to tolerate oral fluids and/or without alternative intravenous access.
2. Place the patient in Trendelenberg position with the CVC exit site positioned below the level of the heart.	Increases CVP	In patient unable to tolerate the Trendelenberg position, the supine position may be used. Elevating the legs may also be done to increase CVP.
3. Ensure that all CVC lumens are capped and/or clamped.	Prevents the movement of air into the CVC	Open lumens provide a direct route through which air can enter the bloodstream.
4. Cover the CVC exit site with gauze and apply gentle pressure while removing the catheter in a slow, constant motion.	Prevents the movement of air into the CVC tract	Failing to cover the exit site and removing the CVC quickly may cause air to move into the CVC tract.
5. Have the patient perform the Valsalva maneuver as the last portion of the CVC is removed.	Increases CVP	Instructing patients and assessing their ability to perform the Valsalva maneuver before the procedure is important, as patients may mistakenly take a deep breath when attempting to perform this maneuver, further decreasing their CVP and increasing the risk of air embolism formation. In patients unable to perform this maneuver, time CVC removal to occur during expiration.
6. Place pressure on the site for 1 to 5 minutes.	Prevents the movement of air into the CVC tract	Promotes hemostasis, allowing the body to start to form a seal over the exit site and close the CVC tract.
7. Apply a sterile occlusive dressing, such as gauze filled with petroleum jelly and covered with a transparent film dressing. Leave dressing in place for at least 24 hours. Change the dressing every 24 hours until the exit site has healed.	Prevents the movement of air into the CVC tract	Plain gauze dressings can permit air to pass through a persistent catheter tract into the bloodstream, resulting in air embolism, as have occlusive dressings left in place for shorter periods of time.
8. Instruct the patient to remain lying flat for 30 minutes after removal of the catheter.	Increases CVP	This allows extra time for the exit site to begin to close and for the occlusive dressing to form a seal before elevating the head and causing a drop in CVP that might cause air to enter the CVC tract.

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