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Navigating Complications: The Unintended Journey of a Guidewire During Dialysis Catheter Placement

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The Case

A 57-year-old man was brought by ambulance to the Emergency Department (ED) from a skilled nursing facility for evaluation of shortness of breath. His past medical history included hypertension treated with lisinopril, diabetes treated with metformin, and poorly characterized heart failure. The patient's blood pressure was 174/101 mmHg, heart rate 126, respiratory rate 26, temperature 37.5^{o} C, oxygen saturation 87% on room air and 94% on oxygen at 8 L/min via rebreather mask. His skin was cool, pale and moist. Diffuse bilateral crackles were heard on chest auscultation. Edema was present in both lower extremities. Chest radiography showed bilateral pulmonary edema. The patient's laboratory results were notable for acute kidney injury and metabolic acidosis, with an estimated glomerular filtration rate of 25, blood urea nitrogen (BUN) 35 mg/dL, creatinine 2 mg/dL, potassium 4.7 mEq/L, sodium 131 mEq/L, bicarbonate 18 mEq/L, and pH 7.29.

After unsuccessful efforts at diuresis, physicians determined that the patient needed dialysis for fluid removal. The dialysis team was called into the ED, and the consulting nephrologist started to place a temporary dialysis catheter (using anatomic landmarks) into the patient's right internal jugular vein. During this procedure, the guidewire was inadvertently inserted into the vessel and could not be recovered. Bedside chest imaging confirmed the guidewire's position. The patient did not complain of any new symptoms and his hemodynamic parameters were stable. However, retention of the guidewire necessitated recovery through emergency operative exploration, which delayed his hemodialysis treatment. After guidewire recovery, the patient responded well to hemodialysis.

The Commentary

By Sharmilee Vuyyuru, DO, and Nandakishor Kapa, MD

This case demonstrates how an adverse event can occur during a common procedure in the setting of failure to use standardized methods as well as variability in operator skill and attention. This patient arrived at the hospital with pulmonary edema and kidney failure; the on-call nephrologist deemed it necessary to place a catheter into the right internal jugular (IJ) vein for emergent hemodialysis. Although this is the preferred location for catheter placement, according to the Kidney Disease Outcomes Quality Initiative (KDOQI),[1] this patient suffered a completely avoidable complication of guidewire loss, which necessitated an operation to recover the guidewire and delayed the initiation of hemodialysis.

When a patient requires emergent dialysis, a central venous catheter is often required to initiate hemodialysis. Before portable ultrasound imaging was widely available, central venous catheters were routinely inserted using anatomical landmarks alone. For instance, to place an internal jugular vein dialysis catheter, the two heads of the sternocleidomastoid muscle and the clavicle were traditionally used as landmarks. This approach has multiple disadvantages when compared with central venous catheter (CVC) placement using ultrasound guidance,[2] as described in recent guidelines from both the KDOQI[1] and the Society for Hospital Medicine.[3] In the largest published meta-analysis, involving 5,108 patients enrolled in 35 randomized or quasi-randomized controlled trials,[4] use of two-dimensional ultrasound guidance reduced the overall complication rate during internal jugular catheter placement by 71% (14 trials, risk ratio [RR] 0.29, 95% confidence interval [CI] 0.17-0.52), inadvertent arterial punctures by 72% (22 trials, RR 0.28, 95% CI 0.18-0.44), and hematoma formation by 73% (13 trials, RR 0.27, 95% CI 0.13-0.55). Ultrasound guidance was also associated with 1.19 fewer cannulation attempts (16 trials, 95% CI -1.45 to -0.92), 57% greater success at the first attempt (18 trials, 95% CI 36%-82%), and 30.5 seconds less time to successful cannulation (95% CI -55.2 to -5.8), on average.[4] This meta-analysis extended and corroborated an earlier meta-analysis of 7 trials involving 830 hemodialysis catheters, which reported 60% (95% CI, 44%-71%) lower risk of cannulation failure at the first attempt, 78% lower risk of arterial puncture (95% CI, 19%-94%), and 73% lower risk of hematoma formation (95% CI, 12%-92%) with ultrasound guidance.[5]

Ultrasound has also been shown to be a valuable tool to detect malposition after insertion, as a multi-center study that reviewed the placement of 758 central venous catheters found ultrasound to be 70% sensitive and 99% specific.[6] Positioning of the CVC was in agreement between ultrasound and chest x-ray in 98.9% of cases, with ultrasound offering more expedient bedside availability.[7] Although the reduction in the complication rate and faster identification of complications are compelling benefits of using ultrasound guidance, proper implementation of this technique requires a standardized protocol and formal clinician training.[7,8] AHRQ's Brief Update Review of the use of ultrasound guidance during central line insertion,[9] included in its Making Health Care Safer II report, highlighted that "educating clinicians on the use of ultrasound for central line placement has received relatively little attention," but "studies have shown that clinical ultrasound guidance skills are improved by implementing simulator-based training." One systematic review of this topic identified several studies reporting improved technical performance and greater learner confidence after simulation training.[10]

Operator competency and attention are essential in preventing CVC insertion complications, including guidewire retention. If the guidewire is secured at its protruding tip, at all times, then it cannot be lost in the vessel. In the largest published series of 236 cases of CVC guidewire retention from England's "Never Event" database (2004-2015), 88% of those with an identified operator (52 of 59) were inserted by trainees.

[11] Causes of guidewire retention were only reported in 38 cases, but operator error, distraction, interruption, and emergency or after-hours pressure were the most commonly cited factors.[11] Four intraoperative guidewire retention cases from Washington University in St. Louis underwent root cause analyses by multidisciplinary teams; all involved urgent and complex procedures in hemodynamically unstable patients. distraction and operator skill as major reasons for this complication.[12] In all cases, at least two CVC kits were opened and at least two guidewires were used, either because initial attempts to thread the catheter failed or because of planned double access of the vein.[12]Inattention blindness or distraction occurred in three cases, either because of concurrent hypotension requiring repeated vasopressor dosing or because the supervising anesthesiologist was simultaneously performing another procedure (i.e., transesophageal echocardiography).[12] Four reported cases from Germany also featured inexperienced operators who were inadequately supervised and distracted by accidental withdrawal of the catheter, premature initiation of the major operation, or information about another sick patient.[13] In the great majority of these and other cases (albeit not the case reported here),[14,15] loss of the guidewire was not recognized when it occurred but was only detected on subsequent imaging or symptom evaluation, indicating a failure to count guidewires or verify removal.

Approach to Improving Safety

Greater consistency in the level of experience needed to perform, and the techniques for proctoring CVC insertion procedures, could help prevent operator errors but pose implementation challenges. Ultrasound guidance can minimize procedure-related complications and facilitate immediate recognition of errors after placement, but such portable equipment is not available at all sites where CVCs must be inserted. Having additional staff at bedside with specific objectives such as counting items at risk of being misplaced and overseeing important steps, including guidewire removal, can help with quicker recognition of complications such as guidewire retention.[12] Having additional staff to monitor vital signs and assist with stabilizing the patient may help to alleviate stress and distractions that would otherwise contribute to inattentional blindness in emergent situations. However, it is occasionally necessary for clinicians to insert CVCs without bedside assistance. Finally, there is agreement about the need to ensure formal training that certifies competency of operators. This training along with required refresher courses and recertification can avoid long gaps between procedure exposure and may be more important than the number of procedures completed.[7]

System Optimization

From the system perspective, having a dedicated CVC team available to perform these procedures may reduce the risk of complications that delay care or compromise patient outcomes. The CVC procedure team would have high training standards and maintain their certification with intermittent proctored training.[3] Such an approach makes it easier to identify and retrain operators when new equipment is introduced, and to debrief after complications occur, but may not be feasible or desirable in all settings of care.

The development of ultrasound with advanced software now using artificial intelligence can also improve needle visualization and tracking, and may reduce the mean number of access attempts, reduce stress from access difficulties, and assist in provider training.[3] Increasing availability of affordable and handheld ultrasound devices in critical care units and EDs will improve access and facilitate ongoing maintenance of

skills in community hospitals where real-time ultrasound machines are in short supply. Access to ultrasound does not guarantee its proper use or the competence of a provider, but it can reduce the number of attempts and resulting distractions, reduce the number of guidewires on the operating field, and motivate ongoing simulation practice and teaching.

In a quality improvement project in Singapore between February 2012 and June 2013, 320 CVCs were inserted in the medical intensive care unit and a medical intermediate care unit using a customized line kit that had drape covers with labels reminding providers to remove guidewires.[16] The project also implemented a structured CVC insertion training program using simulation with hands-on practice, followed by "diligent" attending supervision.[16] Following these quality improvement measures, there were no guidewire retention incidents, trainees felt more confident with the procedure, and trainees reported that the reminder labels were helpful.[16] This study and others suggest that implementing a structured educational training program,[12] standardizing CVC insertion kits and procedures to minimize confusion,[17] and adding reminder stickers to surgical drapes or devices may help to prevent guidewire retention while boosting the confidence of providers during ultrasound-guided CVC insertions.[16]

Take-Home Points

- The use of ultrasound guidance during central venous catheter placement in the internal jugular vein results in fewer complications and fewer attempts at access and should thus be adopted as standard practice when available.
- Operator training for point-of-care ultrasound use along with proctored training in central venous catheter placement, including hemodialysis catheter placement, is important to reduce the risk of guidewire retention.
- Changes in the process of central venous catheter placement to include reminders from staff and equipment kits used during procedures can reduce the risk of complications.
- Widespread availability of portable ultrasound machines and dedicated training with re-certification courses for those who perform central venous catheter placement procedures will increase skill levels and confidence in the providers during high stress situations.

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