Successful Implementation of Electrocardiogram-Placed Peripherally Inserted Central Catheters at a Major Academic Medical Teaching Organization

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Abstract

Health care is becoming increasingly complex. Introduction of new technologies can be overwhelming and complex. The following article outlines the use of a change process theoretical framework to plan, implement, and sustain successful outcomes with integration of electrocardiogram-placed peripherally inserted central catheters at a major metropolitan medical teaching facility.

Keywords: *PICC line, implementation, change*

Introduction

Most of the 37 million people hospitalized each year in the United States have a vascular catheter, with more than 5 million having a central venous access device (CVAD) inserted.[1,2] Nearly all patients admitted to an inpatient care setting require some type of vascular access device for treatment and therapy. The ultimate goal of vascular access device placement is to insert the right device, for the right patient, for the right reasons upon admission.

CVAD placement is commonly done at a patient's bedside without the ability to see the catheter as it travels through the vascular system. After the procedure is complete, confirmation of catheter tip position is typically done with a radiograph. The use of radiography after line placement delays care, even more so if reposition of the tip is necessary. Delays in care can influence both clinical and cost outcomes.[3,4] Given the frequent need for CVADs it is essential that this care process is better understood and managed to achieve higher levels of accountable, patient-focused, and value-driven care.

Health care is increasingly becoming more complex as new technology, innovations, and reform continue to challenge inpatient care. Organizations are constantly looking for ways to streamline patient care and improve overall patient outcomes. Large academic medical centers can be very complex and seemingly obvious improvements can require systems-based thinking and carefully orchestrated attention. The use of theoretical frameworks can provide the necessary structure and momentum to propel change. Early 21st century landmark reports by the Institute of Medicine promulgate the idea that preventable errors and inefficiency in health care can lead to at-risk morbidity and mortality. Furthermore, solutions for sustainable improvement are not achieved by individualized blame, but rather by system redesign and patient-centered approaches.[5] The key to necessary change may be to achieve a common purpose and commitment to structured, systems-based methods.

Systems-based improvement methodologies place patients at the center of all improvement goals. Regardless of the specific improvement methodology, care activities are

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evaluated based on being supported by evidence-based practice, efficiency, and cost. As health professionals we have an inherent obligation to support safe, effective, and efficient patient care. In vascular access this includes evaluating the influence of CVAD tip position on clinical outcomes. In their 2016 guidelines,[6] the Association of Anaesthetists of Great Britain and Ireland make several recommendations for improving the safety of vascular access device insertion. The first recommendation is, "Hospitals should establish systems to ensure patients receive effective, timely, and safe vascular access."[6] There must be an interplay between knowledge, technology, and process within a certain culture of care that when executed well will yield measurable improvement in patient safety, quality, and cost. In peripherally inserted central catheter (PICC) insertion this patient-focused value proposition can be realized with the use of electrocardiogram (ECG) for final tip positioning and confirmation of the most ideal location to prevent unnecessary harm. ECG technology for PICC tip positioning and confirmation can improve the system of vascular access care at any given acute care facility.[3,4,7,8]

Clinical Significance of CVAD Tip Position

To be central and be used both appropriately and safely, a tip of a CVAD needs to be in a great artery of the thorax, at or near the heart, or in a great artery used for infusion in the case lower extremity routes.[9] Ideally, for upper body routes, the tip should terminate in the lower one-third of the superior vena cava (SVC) at or near the junction of the SVC and the right atrium (RA); that is, the cavoatrial junction.[10] There has been controversy on where precisely the tip can safely reside while in situ.[4,8,11] However, there is no debate that malposition of PICC tips out of a safe range can cause and or contribute to the risk of morbidity and even mortality, including dysrhythmias, thrombosis, extravasation, cardiac tamponade, embolus, and infection.[4,10-13] The commonly accepted safe location for CVAD tips, including PICCs, is in the lower one-third of the SVC at or near the junction of the SVC and RA, or even just into the upper right atrium depending on the exact type of CVAD.[4,7,10,11,13] The Infusion Nurses Society standards[10] consider a PICC tip too deep if it goes beyond 2 cm into the RA. A catheter tip too deep can cause cardiac dysfunction if it enters the right ventricle.[12] Even deep RA placement can be an issue with PICCs, especially because tip position is likely to change by several centimeters with arm movement and body position.[4,10] In addition, PICCs are up to 3 times more likely to be mal-positioned compared with other CVADs.[10] A catheter too high in the SVC or even not in the SVC can dramatically increase the potential for thrombosis, up to 16 times greater for high SVC position vs the cavoatrial position, and catheter-associated thrombosis increases the risk for catheter-associated bloodstream infection.[8,10]

Initial placement of CVAD tips to the ideal location, in the lower one-third of the SVC at or near the cavoatrial junction, without guidance can be very difficult. Primary malposition of tips can occur from 2%-30% of the time, with PICCs showing more frequent malposition than other CVADs.[4] Hostetter et al,[8] in a meta-analysis, estimated ideal position with first attempt for CVADs at between 25% and 30%. Considering the recommendation for ideal position exists to avoid potentially life-threatening complications, malpositioned CVADs would need repositioning. Repositioning takes time and resources and requires further manipulation of the catheter after insertion.[3,4,7] More catheter manipulations expose the patient to further risk for infection.[9,10] Subsequent attempts to confirm CVAD position also increases radiation exposure and costs of care.[3,7] Reducing unnecessary radiation exposure is a patient safety initiative, and as such, should be a key consideration for quality improvement efforts in CVAD insertion.[14] Landmark CVAD tip placement can be prone to error and inconsistency. Furthermore, the process of care can be inefficient and costly.

Tip Positioning Anatomy and Physiology

Verhey et al[13] described 3 key factors in an ideal catheter tip position:

1. Located in a high blood flow vessel,
2. Positioned parallel to the vessel with high blood flow, and
3. Has some proximity to a pulsatile and or turbulent flow (near the RA).

Essentially the ideal location to achieve the triad of tip positioning is near or at the beginning of the RA. Anatomically, the RA begins at the crista terminalis and can only be viewed well with a transesophageal echocardiogram (TEE). TEE can also show the catheter tip, but this procedure requires time, sedation, and is impractical for most CVAD insertions.[7] Physiologically, the RA can be found by measuring the maximal P-wave impulse generated by the sinaoatrial (SA) node. This can be achieved by replacing 1 lead, on the arm, of a 3-lead ECG with a intravascular lead; that is, a connection to the catheter with electrically conductive wire or saline. This provides an intravascular impulse instead of a skin surface impulse. ECG is far more practical than TEE at confirming that the catheter tip is near or ate the junction of the SVC and RA.[7] Furthermore, the accuracy of ECG was verified at 100% for a location within 1 cm of the crista terminalis when compared with using surface landmarks at 53% accuracy. The use of technology and more efficient practice can definitely enhance the success of primary tip position at the cavoatrial junction.

Historically, clinicians who insert CVADs approximate the amount of catheter to insert for ideal tip position by using surface landmarks and final confirmation is achieved with radiographic images.[7,8] A clinician needs to know when to stop advancing a catheter and that the catheter tip is positioned correctly with in the vascular system. Chest radiograph interpretation allows an approximation of tip position by using nonvascular landmarks to confirm tip position near or at the SVC-RA junction.[13] This approximation can be subject to image distortion, and only relates to average anatomic relationships between structures, so standardizing care with this