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
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, 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.” 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.

**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. 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. There has been controversy on where precisely the tip can safely reside while in situ. 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. 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. The Infusion Nurses Society standards 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. 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. In addition, PICCs are up to 3 times more likely to be mal-positioned compared with other CVADs. 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.

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.

Hostetter et al, 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. More catheter manipulations expose the patient to further risk for infection. Subsequent attempts to confirm CVAD position also increases radiation exposure and costs of care. Reducing unnecessary radiation exposure is a patient safety initiative, and as such, should be a key consideration for quality improvement efforts in CVAD insertion. 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 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. Physiologically, the RA can be found by measuring the maximal P-wave impulse generated by the sinoatrial (SA) node. This can be achieved by replacing 1 lead, on the arm, of a 3-lead ECG with an 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 at the junction of the SVC and RA. 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. 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. This approximation can be subject to image distortion, and only relates to average anatomic relationships between structures, so standardizing care with this
method can be error-prone.\textsuperscript{8,13} Even reliability and consistency amongst clinicians interpreting tip position with radiographs is inconsistent, partly from image distortion and method used, but also from individual interpretation.\textsuperscript{8,13} Tip position of the CVAD is a critical patient safety issue, and deserves consideration from a system perspective to better align evidence, technology, and process with desired clinical outcomes.

\textbf{Overview of ECG-Guided PICC Lines}

ECG-guided PICCs use 2 external ECG leads in combination with the PICC catheter functioning as the third lead, an intravascular lead. The PICC tip is advanced through the vascular system toward the heart where the SA node emits an electric impulse measured on the ECG monitor as the P-wave. P-wave amplitude or height as seen on the monitor increases as the catheter tip (intravascular lead) progresses toward the target zone, ideally the lower one-third of the SVC to the cavoatrial junction.\textsuperscript{10} The change in P-wave size alerts the inserting clinician if the catheter tip is near the cavoatrial junction (maximum height is achieved at the cavoatrial junction). If the tip goes too far the P-wave becomes biphasic in addition to smaller height or amplitude.\textsuperscript{4} If the tip is pulled back, the biphasic pattern will go away and maximum height will be seen again. As described earlier, the SA physiology of the P-wave very accurately determines tip position at or near the anatomically desirable cavoatrial junction. A printed ECG strip with P-wave progression is printed and placed into the medical record, and the inserting practitioner calls the ordering provider to alert them that the technology has been used for insertion and an order for line use is necessary. ECG guidance eliminates the need for a postinsertion chest radiograph to verify tip placement, allowing for the catheter to be used almost immediately after placement and ultimately saves patients from unnecessary radiation exposure and further catheter manipulation.

For example, with non-ECG-guided PICC insertion, after catheter placement an order from a provider to use the PICC could be dependent on verification of the tip placement on chest radiographs interpreted and documented by a radiologist. The time associated with this set of steps and processes varies in many organizations depending on resources and communications between the ordering provider, PICC-inserting practitioner, and radiologist confirming the PICC tip placement. Elimination of the need for radiographic documentation and interpretation streamlines patient care and decreases time between insertion and time to use of the PICC line.

ECG technology is currently approved by the Food and Drug Administration for patients aged 18 years and older. However, there are limitations to the use of ECG technology when interpretation of the external or intravascular ECG P-wave is difficult. Inability to measure a P-wave may occur in patients who present with heart rhythm abnormalities, atrial fibrillation, atrial flutter, severe tachycardia, or presence of cardiac rhythm devices.\textsuperscript{15} In cases where there is suboptimal detection of the P-wave, the manufacturer recommends against use of ECG-guided PICC.\textsuperscript{15} In these patients a default protocol would likely be the use of chest radiograph followed by radiologist interpretation.

ECG for PICC placement has been available in Europe since 2006 with studies documenting the accuracy and efficiencies in placement published in 2008.\textsuperscript{16} ECG technology for PICC insertions has been approved by the Food and Drug Administration and become more popular in the United States during the past 5 years, with several published studies on the accuracy of tip placement and benefit of decreased radiation exposure.\textsuperscript{3,16-19} There are few to no guidelines available on how to navigate a complex major academic medical center in successful implementation of ECG-guided PICC technology.

\textbf{Theoretical Framework}

An appropriate framework can help guide any new initiative or change process. The structure and conceptual foundations aligned in the framework should support the initiative at hand. Founded on Kotter’s original 8-step process of organizational change originally published in 1996, Accelerate’s 8-step process—or theory—for change uses the same steps but now conceptualizes them in a concurrent and continuously implemented fashion.\textsuperscript{20} The 8 steps include:

1. Creating a sense of urgency,
2. Building a guiding coalition,
3. Forming a strategic vision,
4. Enlisting volunteer army,
5. Enabling action by removing barriers,
6. Generating short term wins,
7. Sustaining acceleration, and
8. Instituting change.

The change process is dynamic and does not occur in a progressive step-like fashion but rather is constantly evolving. Kotter’s theory can be organized in 3 phases. The first is creating a climate for change, which includes creating urgency, building a coalition, and forming vision. The second phase is engaging and enabling the whole organization, which includes enlisting an army, removing barriers, and generating short-term wins. The third phase, implementing and sustaining change, encompasses sustaining acceleration and instituting change. In all, Kotter’s theory for organizational change was the guiding framework driving the process implementation of ECG-placed PICCs at our institution. See Figure 1.

\textbf{Process Implementation}

Successful implementation of any new program or quality initiative in health care requires solid leadership and change management with thoughtful planning, communication, training/education, collaboration, and partnership to sustain results. The successful implementation of ECG-placed PICCs will be discussed in terms of the 3 phases of Kotter’s change process framework. It should be noted that this initiative was reviewed and considered exempt from the institutional review board process.

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Creating a Climate for Change

Preparation and appropriate buy-in from key stakeholders is essential to building a solid foundation for change. The first steps taken by the nursing patient care director (PCD) of the Vascular Access Department was to involve the practitioners who would be affected in an open discussion about implementation and benefits of the new technology, including a review of available literature. Highlighted were the benefits of saving patients from radiation exposure, accuracy of ECG placement compared with subjective radiographic interpretation, and decreasing time spent verifying radiographic images ultimately streamlining patient care. Meetings with sales representatives for ECG devices to fully understand the technology and options for implementation were scheduled and all staff had the opportunity to engage in dialogue and questions regarding implementing ECG for PICC line placement. Ultimately, the staff was instrumental in deciding which company and product would be best for patients.

The nursing PCD worked with the unit’s medical director to identify other medical provider groups that would need to be included in the implementation and plan for the entire organization. Coordination of a practice change would need to be implemented across the health care system. The organization, a major metropolitan medical teaching facility, is a system with 2 academic medical schools at separate locations and 6 main campuses. A staged approach was decided upon. First, a selected academic medical center would go live, then after successful implementation the second would go live, and so on until the technology was implemented at all campuses. Specific attention was made in timing at specific sites to avoid conflict with competing initiatives.

Figure 1. Kotter’s (2014) organizational change.
Kotter’s next step in creating a climate for change is building a guiding coalition. To achieve this, it was necessary to understand what groups of providers would need to be engaged in the initiative. First and foremost, engagement of members of the Radiology Department was imperative. A specific meeting to discuss the technology was set up and a partnership was formed with support from senior leadership in the Radiology Department. Several key providers in the Radiology Department were selected to work on the successful implementation and were part of a core team. It was the decision of the medical director of vascular access and executive vice chairman of radiology to perform an internal clinical trial and gather data on the accuracy of the technology.

During the course of this meeting the nursing PCD, medical director of vascular access, and executive vice chairman of radiology also identified other key provider groups, including the medical service line chairs, unit medical directors, Radiology Department staff, Interventional Radiology Department partners, nursing leadership and staff, and collaboration with affiliated home care nursing associations.

Kotter is clear in his framework for implementing change that formation of a vision is an important step to success. Therefore, the nursing PCD, medical director of vascular access, and the executive vice chairman of radiology applied a guiding vision for ECG-guided PICCs that aligned with the organization and Vascular Access Department. Overall, the vision centered on being recognized for excellence in teamwork while providing the most efficient, effective, and best vascular access services possible for patients.

Engaging and Enabling the Whole Organization

Having a unified and clear approach to implementation is important. Immediate steps in engaging the entire organization started with enlisting a volunteer army. For this implementation the volunteer army was the Vascular Access Department (VAD) nursing team in collaboration with the coalition of the key stakeholders. However, the real drivers of the program would be those who were using the technology. The core team of VAD practitioners consisted of approximately 30 registered nurses. A total of 6 registered nurses agreed to go through extensive online and hand-on training for execution of the trial and evaluation of the ECG technology. The remainder of the team was encouraged and expected to participate and engage in educational sessions to be informed and build a sense of teamwork and support for the whole unit.

There were several conversations and meetings that occurred with the nursing PCD, medical director, and VAD team registered nurses to discuss what possible obstacles might come up. Identified was concern about lack of support from the Radiology Department because decreased films may result in decreased revenue. However, the partnerships that were established with the Radiology Department focused on what is best for patients. There was also confusion on what to do for which type of PICC line to be inserted (ie, traditionally placed PICC lines requiring postinsert chest radiographic interpretation vs ECG-placed PICCs). As a result, the algorithm in

Figure 2 was created for dissemination and to guide the process for ordering and completing traditional and ECG-placed PICC insertions.

Appropriate communication was also a potential barrier so both a nursing memo supported by the chief nursing officer and provider memo supported by the chief medical officer and chief quality and patient safety officer were distributed before go-live. Realizing that a memo is not enough, the medical director and nursing PCD attended meetings with each constituent group to prepare for the implementation. The department heads and leaders of each group were asked to disseminate the information back to their teams. All departments were able to bring any questions or concerns back to the nursing PCD of the Vascular Access Department and/or medical director for discussion.

Due to these efforts, at go-live both the nursing VAD team and the medical providers were prepared and enthusiastic. To capitalize on the positive momentum, a daily debriefing of ECG-guided PICCs placed was completed with the VAD team trial members and nursing PCD. At the end of each week the executive vice chairman of radiology, medical director of vascular access, and nursing PCD of vascular access met to review all ECG-guided PICC lines placed. The first 100 patients who received an ECG-guided PICC insertion were enrolled into a trial and the resulting data convinced Radiology Department staff and nursing staff to proceed with the change. Overall, our internal trial outcome data with the ECG-guided PICC technology was consistent, accurate, and superior to the current technology.

Implementing and Sustaining Change

At the end of the trial, the data were shared with the VAD team in collaboration with the nursing PCD, medical director, and executive vice chairman of radiology. There was unanimous agreement among the VAD leadership and VAD team nurses to move forward with full implementation and training for all vascular access staff members to use the technology. Over the course of the next 4 weeks, the remainder of the VAD team nurses were trained to place ECG-guided PICC lines and successfully completed competencies in ECG-guided PICC line placement.

Throughout the implementation, the leadership of this initiative continued to occupy regular agenda spots during key institutional meetings, including the nursing leadership forums and a medical leadership group house staff quality council. Any issues, concerns, or knowledge gaps identified were addressed in these meetings. The proactive approach resulted in very little opposition to the implementation of ECG-guided PICCs. If there were any providers who had concerns, the medical director and executive vice chairman of radiology initiated a peer-to-peer conversation to discuss.

Data with the total number and percentage of patients who successfully had an ECG-guided PICC placed not requiring a chest radiograph, the total time saved from eliminating chest radiographs postplacement, and any reasons for failure were tracked and reported. This feedback served to keep
the VAD team focused on their outcomes and successes over time.

To continue to improve VAD nurses’ skills, special educational in-services were set up at regular intervals for the first year after implementation. Expert nursing education clinicians would come and discuss and review various P-wave tracings and present case studies.

A peer review process was developed where VAD nurse experts began reviewing peers’ practice and providing formal feedback. Lessons learned during implementation at the first campus were in turn shared with the next campus to go live and the tiered approach to implementation continued on in succession over the course of a year until all campuses were live with the new ECG technology.

Conclusions

Vascular access devices are critical to efficient and effective modern health care delivery. As such, current methods of improving patient care and achieving better quality and value from care should be applied to this care activity. Viewing vascular access as a system of care can help to focus efforts on the most meaningful, patient-centered aims for change.

More than 5 million CVADs are placed every year, and if not done with ideal tip positioning patient harm may result. There are still more than 30,000 CVAD infections per year according to the Centers for Disease Control and Prevention. Malpositioned CVADs may contribute to life-threatening situations. The health care system should be actively evaluating new technologies, evidence, and processes in CVAD insertion tip positioning to make this care safe and more cost-effective. This is in keeping with landmark reports and initiatives from the Institute of Medicine and Institute for Healthcare Improvement. More efficient and safer PICC tip positioning is a professional imperative.

Overall, implementation of ECG-guided PICC lines was successfully completed in a large academic tertiary care hospital using Kotter’s framework for organizational change. Although Kotter’s framework was a guiding force behind the successful integration of the new technology into the culture, other best practices should be highlighted that contributed to the overall success. Communication approaches, enlisting engagement of key individuals, meaningful planning keeping the unique culture and key stakeholders in the organization in mind, opening up and listening to concerns in various forums, as well as thorough follow-up and ongoing data collection all led to a successful implementation and sustained overall culture change in PICC insertion technology at our organization.

Figure 2. Provider peripherally inserted central catheter (PICC) algorithm. MD = medical doctor; PA = physician assistant; NP = nurse practitioner; ECG = electrocardiogram; RN = registered nurse; CXR = chest radiograph.
Disclosures
The authors have no conflicts of interest to disclose.

References