Improving Patient Safety and Reducing Hospital Costs: The University of Washington Central Venous Catheter Project

Edgar J. Figueredo MD, Mika N. Sinanan MD PhD, Vanessa Makarewicz RN MN, Sara Kim PhD, Andrew S. Wright MD.

Institute for Simulation and Interprofessional Studies (ISIS), University of Washington, Seattle, WA.

Introduction

Central Venous Catheterization (CVC) is one of the most common invasive procedures performed in modern hospitals. Up to 48% of patients in the Intensive Care Unit have a catheter placed, with 15 million CVCs inserted every year. Catheters are also frequently placed in the Emergency Department, the Operating Room, and in Interventional Radiology.

Unfortunately, the rate of complications from CVC is quite high, with studies demonstrating a complication rate between 5% to 29% (1). Mechanical complications associated with this procedure include failure to place the catheter, pneumothorax, arterial puncture, pulmonary embolism, air embolism, dysrhythmia, and death. Each year in the United States there are around 80,000 Central Line Associated Blood Stream Infections (CLABSI). These infections are common, costly, and potentially lethal, resulting in up to 28,000 deaths among patients in ICUs (2). According to the National Nosocomial Infection Surveillance System of the Centers for Disease Control and Prevention, the median rate of CLABSI in ICUs of all types ranges from 1.8 to 5.2 per 1000 catheter-days (3). A CLABSI increases ICU and hospital length of stay by 5 and 7 days, respectively. The average cost of care for a CLABSI is $45,000, with an annual cost in the United States estimated between $296 million to $2.3 billion (4). In 2008 the Center for Medicare and Medicaid Services (CMS) declared that CLABSIs are a ”never event” and will no longer pay for care related to CLABSIs.

A number of interventions have been suggested to reduce the rate of catheter-related complications. Routine use of ultrasound guidance during line insertion significantly reduces the risk of pneumothorax and arterial injury. Luminal pressure monitoring (manometry) may further reduce arterial injury. In order to reduce the infection rate, the Institute for Healthcare Improvement (IHI) has developed a central line bundle of hand hygiene, chlorhexidine skin antisepsis, maximal barrier precautions upon insertion, optimal catheter site selection, and daily review of line necessity with prompt removal of unnecessary lines (5). Compliance with this bundle has been shown to significantly reduce the incidence of CLABSI.

At the University of Washington we recognized that compliance was less than optimal in standards, with significant variation in care. Internal review revealed that this variation in care was due to several issues including: 1) lack of knowledge in modern concepts in CVC such as maximal barrier precautions, 2) lack of training in ultrasound-guided CVC placement, and 3) lack of standard technique and equipment. A materials management issue accompanied this, as equipment such as ultrasound machines, barrier drapes, sterile gowns, and standard CVC kits were not always available at the bedside.

Training in CVC catheterization prior to this initiative depended on the clinical service and had not been standardized. For trainees, introduction to CVC followed the typical Halstedian education model with learning occurring during performance of the procedure (under supervision) on actual patients. The limitations of this approach are well established. For example, in one study, successful first cannulation occurred in 37% of the residents trained under the Halstedian model, with a CVC insertion success of 67%, compared to 51% and 78% respectively of the residents trained with simulation (6). At the University of Washington, while some departments did use the simulation lab to practice CVC placement, this did not follow an established curriculum and often did not include didactic training in topics such as indications, technique, or error recognition and management. Additionally, because most faculty physicians and senior residents had learned a landmarked-based approach rather than the safer, ultrasound-guided technique, this deficit was typically passed down to junior trainees. For nurses, on-the-job training led to a lack of standardization and variance between clinical units.

We committed ourselves to change the culture and practice of care in CVC through an approach of intensive simulation-based education combined with a system-wide quality improvement process. This required careful consensus building around best practices and agreement on a standardized process of care, followed by the development of training modules, a plan for implementation, and changes to clinical practice.

Based on the concept that this was a system-wide issue, we determined (with the full backing of health system administration) to require compliance by all departments, all physicians (including senior faculty physicians), physician assistants, and advanced practice nurses who place central lines. It rapidly became clear that nursing staff, patients, and their families also needed specific and targeted education. We engaged our academic training hospitals to modify the medical staff credentialing process to explicitly include satisfactory completion of the simulation-based curriculum for CVC placement, and included all relevant Department Chairs in our work. We feel that these were critical steps in attaining system-wide culture change and compliance with best practices.

In order to reach consensus on best practices and standardization, we built a team of experts including physicians from multiple departments (surgery, critical care, and anesthesiology), nursing staff, hospital administration, infection control, risk management, and a PhD medical educator. Curricula was exhaustively reviewed and put on a regular update schedule and mounted on our enterprise learning management system for systemic tracking for credentialing purposes. Our three-part plan to improve patient safety surrounding CVC included 1) a cognitive trainer for didactic education, 2) a technical skills simulation for both training and evaluation of proficiency, and 3) a system-wide quality improvement process.

Design and Implementation of the Cognitive Trainer

The first step in design of the cognitive trainer was developing content. When it became clear that some information was needed by both physicians and nurses, we split the program into three modules: one for all trainees (focused on indications, scheduling, and patient preparation), one for physicians and other providers who place lines (focused on technical issues around positioning, sterile barrier use, ultrasound, vein access, wire and catheter insertion, and fixation), and one for nurses alone (focused on monitoring, documentation, and maintenance of CVCs). A patient and family education module was also developed. Ultimately the key topics were agreed upon, as seen in Table 1. In order to make the program as engaging as possible, it was designed to be an online module with interactive anatomy demonstrations and copious use of video. Screenshots from the trainer are seen in Figures 1 and 2. At completion of the online training comprehension is assessed with a multiple-choice examination.

An important aspect of the training is the team component. In the past, physicians typically placed CVCs without participation by nursing staff. This led to poor team coordination, safety issues with inconsistent patient monitoring, and limited compliance with documentation of standard processes of care. As described further below, part of the QI process involved requiring nursing presence during line placement and use of a standardized checklist. This culture shift required special attention in our training. Because our hospital is also in the process of adopting the TeamSTEPPS program (which is an evidence-based teamwork system aimed at optimizing patient outcomes by improving communication and teamwork skills among health care professionals), language and skills from this program were incorporated into the CVC training, including concepts such as “stop-the-line” criteria and the “two-challenge” rule.

Design and Implementation of the Technical Skills Simulation

The first step in designing the technical skills simulation was to agree on a standard process for line insertion for clinical practice. This required consensus building between physicians from multiple departments, as well as input from hospital administration. We then aligned the technical skills simulation with the agreed-upon standardized process.

A key feature of the technical skills simulation is that it is a “full-procedural” simulation (Figure 3) carried out at various sites of the UW Medicine Institute for Simulation and Interprofessional Studies (ISIS), our enterprise simulation center. In the past CVC training in the simulation lab was often limited to just the needle and guidewire insertion, which many physicians viewed as the most difficult and most technical portion of the procedure. We felt that it was important to include the entire procedure from patient consent to final verification of proper line positioning in order to ensure that all learners are comfortable with the entire standardized process for line placement.

During training and cerrtification, the simulation takes place at four stations:

1) Patient Preparation,
2) Internal Jugular Needle and Guidewire insertion,
3) Subclavian Needle and Guidewire Insertion, and
4) Catheter Advancement and Completion.

We have found that the use of multiple stations has some practical benefits. First, the flow allows for multiple examiners and examinees to work in an assembly-line fashion, improving throughout when training or certifying large numbers of physicians.

Second, a common problem in CVC simulation is rapid degradation of simulated tissue. We have tried ultrasound-compatible simulators from a number of third party suppliers, and currently use the CentraLineMan System® (Simulab,Seattle, WA, USA). Once the simulated tissue has been dilated for catheter insertion, leakage makes it unusable for additional training sessions. By using multiple stations we can cycle the simulated tissue from the most pristine (setup) to the less damaging (needle and guidewire insertion). Typically a simulated tissue can withstand 10-20 training sessions at the second and third stations, as long as the tissue is not dilated. Once the tissue is no longer suitable for needle insertion it is cycled to the final station, where a guidewire is left permanently in place. It can then be used for multiple dilations and catheter placements before being discarded.

The technical skills simulation is used as an educational tool and then as an evaluation of basic proficiency. We therefore developed an assessment tool consisting of a checklist and global rating. The simulation checklist includes all elements of the clinical checklist developed as part of the system-wide Quality Improvement (QI) process (see below) with additional elements to assess technical skill. This tool has subsequently been validated in a single-center study. Multi-institutional and multi-specialty validation is underway. Every trainee is required to complete every step of the procedure properly to be “certified” for proctored clinical CVC placement.

Design and Implementation of System-Wide QI Process

In parallel with our efforts to develop and implement our enhanced educational process, we also began a comprehensive system-wide quality improvement process. The full backing of hospital administration and the leadership of key clinical departments supported this effort. A key component of this QI process is the establishment of, and requirement for a clinical checklist for CVC insertion. This mandates and documents compliance with key elements of our standardized protocol such as patient preparation, hand hygiene, use of ultrasound, and more recently arterial pressure monitoring (manometry) for CVC lines, as well as patient monitoring. It also reinforces the team components of the procedure, including specific callouts for a team pre-procedure huddle and identification of “stop-the-line” criteria.

A major additional effort has been placed into documentation and tracking of all lines. Our electronic medical record was modified to allow structured charting of line insertion, routine line care, and line removal. “Structured” data in these notes can be extracted for Quality Assurance (QA) purposes. Each line is now tracked throughout its hospital course by dedicated nursing staff, and a daily list of all lines is generated for nursing leadership. The list includes the patient identifiers and unit, the length of time the line has been in place, and the reason for the line. This list is then reviewed to assess the indications for and necessity of the line.

The third component of the QI process was to improve the availability and accessibility of equipment. We standardized the CVC disposable kits with our vendor and worked extensively with materials management to develop and stock line carts that contain all necessary supplies, including spare guidewire, sterile gowns, gloves, and barrier drapes. Ultrasound machines were also purchased and sited throughout the hospital. A line cart and US machine are now available in every unit where lines are placed.

Challenges

Perhaps surprisingly, there has been relatively little conflict in developing a consensus regarding a standardized CVC insertion process. The major challenge in this process has been the intense manpower effort required to implement and sustain the move to standard training, credentialing, and tracking. The initial investment in developing the standardized clinical process and the educational initiative has been followed by ongoing work to track results and maintain the ongoing quality improvement process. This has been a major initiative by hospital administration, and the team involves more than 20 people from different clinical and administrative departments. We currently meet twice monthly to discuss cases, address ongoing issues, and plan future revisions.

An additional challenge has been the costs associated with implementation of the educational curriculum. Initial funding for development of the online training modules and the technical skills simulation came from internal funding sources, and cost an estimated $70,000 to $100,000 per year, plus the support costs for dedicated nursing staff. Additionally, this cost does not account for all of the faculty time and FTE spent in development. Additional costs are accrued annually for maintenance and updates to the curriculum. The training/evaluation costs of the technical skills simulation are estimated to be $66.48/person. Costs are minimized through reuse of simulated tissue (as noted above) and use of outdated and vendor-donated, nonsterile CVC kits for the simulation lab (ISIS), which drives costs down to $22.48/person. While the ISIS bears the costs of materials, equipment, and technician FTE, each department is responsible for providing their own faculty for training and evaluation sessions.

There was some initial resistance regarding the requirement for certification from faculty long used to placing CVCs. Departmental and divisional presentations, information about the training program, and an efficient process for credentialing contributed to effective consensus building. Many faculty noted value to their own practice from reviewing the state of current practice and our training program. Essential to our program was certification for every provider including all faculty who place or supervise CVC placement. Some faculty did decide to stop placing or supervising line placement, helping to maintain volume for others that serve to help maintenance of skills for the rest. In addition, we have noted a progressive decline in the number of CVCs (33% reduction) as more standard indications reduce the rate of CVC placement, including reductions in our CVC placement in the ICU.

Results and Current Directions

To date we have now certified more than 1150 physicians through the combined didactic and technical skills simulation. We have performed several evaluations of the effectiveness of our training platform. Pre/Post testing on the multiple choice examination shows improved knowledge after completion of the training. More importantly, completion of the technical skills simulation dramatically improves compliance with the checklist (from an average of 22 checklist errors before training down to 3 after training).

Having now trained and certified all faculty physicians and trained active nursing staff, we are now moving into a mode of maintenance of certification. We are currently developing an annual refresher/update module for nursing staff, residents, and currently credentialed faculty. It is unclear how often demonstration of proficiency in the simulation lab should be required, and whether or not this should be impacted by clinical volume. It may be that physicians who place less then a certain number of lines per year should be required to demonstrate continued proficiency on a more frequent basis.

Clinically we have seen improved compliance with and documentation of the central line bundle, from 0% documentation in January of 2008 to near 100% currently. The rate of CLABSI at the two hospitals involved in this project has progressively reduced over the course of our training since 2008, decreased by roughly 200% to a rate that is consistently below 0.9 CLA-BSI/1000 catheter days.

Although there were significant costs involved in development of this program, based on our internal surveillance data we estimate that it prevents 35 line complications per year, saving $30,000 dollars per complication, for a total savings of $1,050,000 annually. We have also realized savings from materials management as we have standardized our equipment and reducing the number and types of line being stocked. Therefore we conclude that the investment in time, personnel, and money has been more than recouped in improved patient safety and reduced hospital costs. We feel that this program of a combined educational and quality improvement initiative can serve as a model for other clinical scenarios.

Table 1: Key Topics for CVC Cognitive Training Modules

MD/RN Module

Indications
Contraindications
Alternatives
Risks
Team Approach

- MD/RN roles
- Pre-procedure huddle
- Time-Out process
- RN Cross-Monitoring
- Checklists
- “Stop-the-line” criteria
- “Two Challenge” rule

Standard Protocols for:

- Care after insertion
- Daily review of line necessity
- Line Removal
- Catheter Exchange

MD/Provider Module

Supplies and Setup

- Sterile Technique
- Barrier Precautions
- Patient Preparation
- Patient Positioning
- Local Analgesia

Anatomy
Ultrasound
Manometry
US-guided Technique
Catheter Exchange
Complications

- Air Embolism
- Arterial Cannulation
- Bleeding
- Arrhythmia
- Loss of Consciousness
- Hypotension
- Hypoxia
- Inability to advance or remove guidewire
- Inability to Achieve Blood Return
- Pneumothorax

RN Module

Line types
CVC Bundle

- Daily review of line necessity
- Hand hygiene
- Chlorhexidine scrub

Dressings
Maintenance of IV tubing and supplies
Documentation
Blood draws
Drug/IV administration
Blood cultures
Bathing

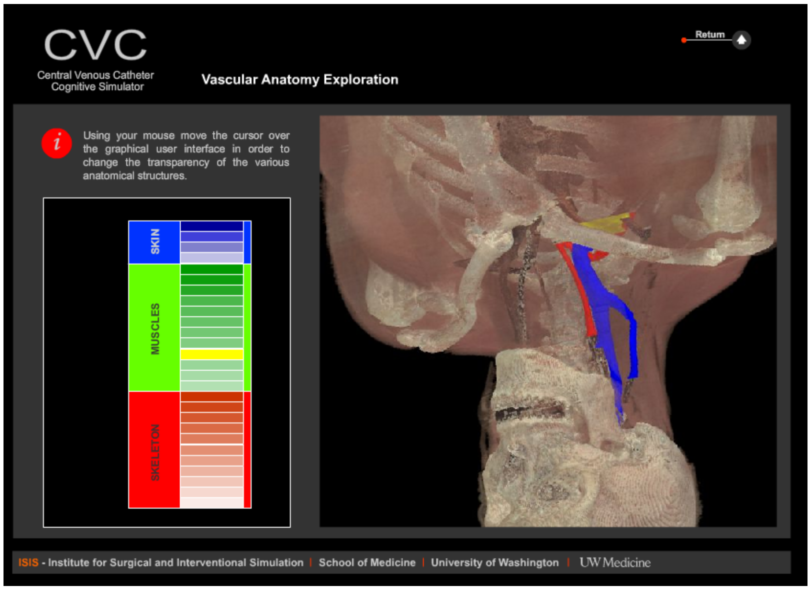

Figure 1: Interactive demonstration of relevant anatomy

Figure 2: Video demonstration of Ultrasound-guided CVC insertion

Figure 3: Full Procedural Simulation

Bibliography

1. McGee DC, Gould MK. Preventing complications of central venous catheterization. N Engl J Med. [Research Support, U.S. Gov't, Non-P.H.S. Review]. 2003 Mar 20;348(12):1123-33.

2. Klevens RM, Edwards JR, Richards CL, Jr., Horan TC, Gaynes RP, Pollock DA, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep. 2007 Mar-Apr;122(2):160-6.

3. National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control. [Research Support, U.S. Gov't, P.H.S.]. 2004 Dec;32(8):470-85.

4. O'Grady NP, Alexander M, Dellinger EP, Gerberding JL, Heard SO, Maki DG, et al. Guidelines for the prevention of intravascular catheter-related infections. Centers for Disease Control and Prevention. MMWR Recomm Rep. [Guideline
Practice Guideline]. 2002 Aug 9;51(RR-10):1-29.
5. Institute for Healthcare Improvement. Cambridge M. How-to Guide: Prevent Central Line-Associated Bloodstream Infections. . (Available at wwwihiorg) [serial on the Internet]. 2012.
6. Evans LV, Dodge KL, Shah TD, Kaplan LJ, Siegel MD, Moore CL, et al. Simulation training in central venous catheter insertion: improved performance in clinical practice. Acad Med. [Randomized Controlled Trial
Research Support, U.S. Gov't, P.H.S.]. 2010 Sep;85(9):1462-9.