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Major article

A multitiered strategy of simulation training, kit consolidation, and electronic documentation is associated with a reduction in central line–associated bloodstream infections

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Background: Simulation-based training has been associated with reduced central line–associated bloodstream infection (CLABSI) rates. We measured the combined effect of simulation training, electronic medical records (EMR)-based documentation, and standardized kits on CLABSI rates in our medical (MICU) and surgical (SICU) intensive care units (ICU).

Methods: CLABSI events and catheter-days were collected for 19 months prior to and 37 months following an intervention consisting of simulation training in central line insertion for all ICU residents, incorporation of standardized, all-inclusive catheter kits, and EMR-guided documentation. Supervising physicians in the MICU (but not the SICU) also completed training.

Results: Following the intervention, EMR-based documentation increased from 48% to 100%, and documented compliance with hand hygiene, barrier precautions, and chlorhexidine use increased from 65%-85% to 100%. CLABSI rate in the MICU dropped from 2.72 per 1,000 catheter-days over the 19 months preceding the intervention to 0.40 per 1,000 over the 37 months following intervention ($P = .01$) but did not change in the SICU (1.09 and 1.14 per 1,000 catheter-days, $P = .86$). This equated to 24 fewer than expected CLABSIs and $1,669,000 in estimated savings.

Conclusion: Combined simulation training, standardized all-inclusive kits, and EMR-guided documentation were associated with greater documented compliance with sterile precautions and reduced CLABSI rate in our MICU. To achieve maximal benefit, refresher training of senior physicians supervising practice at the bedside may be needed.

Vascular catheter-related bloodstream infection (CRBSI) has been attributed to up to 28,000 potential annual deaths in the United States, at an estimated annual cost of up to $2.3 billion per year.[1] A landmark study in 2006 demonstrated that strict adherence to a bundled practice of hand hygiene, full barrier precautions, chlorhexidine skin antisepsis, femoral site avoidance, and judicious early line removal can dramatically reduce the rate of CRBSI to nearly 0%.[1] Subsequently, in 2007 the Centers for Medicare and

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Medicaid Services identified CRBSI as a preventable complication of health care and no longer reimbursed a complication of hospital stay in the United States.[2] As part of their 2009 National Patient Safety Goals,[3] the Joint Commission advocated for widespread implementation of evidenced-based guidelines to reduce the rate of CRBSI, and this practice is now the standard of care for hospitals nationwide. Nevertheless, strict adherence to this practice has proven difficult to document and enforce.

With federal funding-based incentive for hospitals to transition over to "meaningful use" of electronic medical records (EMR),[4] several hospitals are implementing EMR-based documentation systems to help guide practice and enforce tighter adherence to best practice standards. A recent study demonstrated that EMR-based procedure notes, including evidence-based elements of best practice for central line insertion, was linked to an increase in documented compliance.[5] The effort to improve patient safety and reduce procedure-related complications has also led many institutions to move away from traditional, experience-based learning in real patients, toward training physicians via mannequin-based simulation. This type of "low stakes" learning can facilitate procedural skills acquisition with opportunity for constructive feedback and no added risk of patient harm.[6] In fact, such "simulation-based" training of "resident" physicians in central venous catheter placement has now been shown to improve mastery of skills and reduce immediate complications[7,8] and was recently linked to reduced catheter-related infections.[9,10] We thus sought to determine whether the combined implementation of EMR-based documentation and mandatory simulation training of resident physicians in sterile technique and central line insertion would lead to an improvement in documented compliance with sterile technique and a reduction of central line-associated bloodstream infections (CLABSIs) in our intensive care units (ICUs).

MATERIALS AND METHODS

This study was approved and granted a waiver of consent after formal review by the Committee on Human Research Protections at the University of Vermont (UVM) and did not conflict with any local or national laws. The study was conducted in the ICUs of Fletcher Allen Hospital, a 400-bed academic hospital affiliated with the UVM, in Burlington, Vermont. The medical and surgical intensive care units (MICU and SICU, respectively) are each 21-bed units on adjacent but separate floors in the hospital, staffed by residents, fellows, and UVM Medical Group physicians. The MICU is an entirely closed unit, exclusively managed by a MICU team (ICU physician, fellow, and residents), who are responsible for placing all central lines. The SICU is a partially closed unit, with all critically ill patients managed by a SICU team, but some noncritical post-operative patients managed by a surgical team. The majority of central lines placed on SICU patients are placed by the SICU team or anesthesiologists in the operating room. Prior to this initiative, both ICUs utilized centralized central line supply carts and a paper-based checklist of bundled procedural protocol, both which were based on the prior work of Pronovost et al,[1] but compliance was sporadic and challenging to audit. Per routine policy, the CLABSI rates in both ICUs are monitored and reported on a monthly basis. In accordance with the Centers for Disease Control and Prevention's National Healthcare Safety Network, CLABSI was defined as a primary bloodstream infection (BSI) in a patient who had a central catheter in place within the 48 hours preceding the BSI, and cannot be directly linked to infection at another site.[11,12] Whereas the term "CRBSI" attempts to more thoroughly link the BSI to a central catheter, it can be less sensitive and is rarely used for surveillance purposes.[12] Hence, CLABSI rates were collected continuously from January 2009 to August 2013, 18 months prior to (and including July 2010 for 19 total months) and 37 months following implementation of mandatory simulation training in central venous catheter placement. The same data collection methods and definition of CLABSI were used throughout the study period. Audits of compliance with sterile barrier precautions and EMR-based documentation were carried out once a month on cross samples of an average of 18 to 19 ($\pm$1.25) patients per audit by the hospital's quality department for the first 2 months preceding and the first 24 months following the intervention.

During simulation training, physicians were instructed by 1 of 2 designated vascular access nurses or physicians on sterile technique and barrier precautions, which included enforcement of all caregivers in the room wearing a cap and mask, instruction on sterile gowning and "closed-sleeve" gloving technique,[13,14] chlorhexidine antisepsis of the skin, sterile draping of the patient, and periprocedural maintenance of the sterile field.[12] Physicians were then trained by 1 of 2 physician-instructors in landmark identification, proper equipment preparation, and "Seldinger technique" for subclavian vascular access using Blue Phantom (CAE Healthcare, Sarasota, CA) neck and upper torso vascular access mannequins, followed by proper placement of a sterile, self-adherent dressing. Because of time constraints and significant overlap in steps, subclavian access was followed by review of landmarks and practice venipuncture of the internal jugular vein. Instructors developed an a priori checklist of mandatory steps adapted from Barsuk et al, previously shown to promote mastery of procedural skills.[7] This checklist was used to guide initial demonstration of line placement and then used for competency evaluation of trainees during a supervised simulation exercise.

To minimize the number of needed steps to comply with sterile practice[15] and eliminate the need for transferring equipment onto the sterile field, the hospital entered a contract with their central line kit provider to assemble custom, self-enclosed, and "complete" central line kits, including needleless port adaptors, sterile saline, and occlusive dressings (all previously separate). These kits were used for simulation training. After completion of simulation training, physicians were guided through an EMR-based procedure note, the first section of which documented compliance with "best practice" in minimizing risk of CLABSI[12] and was filled out by the nurse at the time of the procedure, and the second portion of which was completed by the physician. The documentation was not considered complete until the physician generated a procedure note, which autopopulated itself with all "check listed" elements filled out by the nurse and physician. At completion of training, the instructor signed the resident off as being competent for additional supervised training in the hospital.

The new kits, simulation training, and EMR-based documentation were all introduced as part of the initiative in July 2010. The training initiative began in July 2010 for residents entering the ICU in August 2010 and was thereafter delivered to all resident physicians 1 to 2 months before they rotated in either ICU. Over the first 3 months following July 2010, all 6 critical care fellows and 10 MICU attending physicians, underwent identical "refresher" training, including the training on closed-sleeve gloving and maintaining a sterile field. Senior SICU physicians and anesthesiologists placing catheters in the operating room and SICU did not attend the refresher training. As part of existing policy, physicians were encouraged to let clinical factors guide their own choice between subclavian or internal jugular access; femoral lines were strongly discouraged and carried a removal mandate after 24 hours.

CLABSI events were recorded monthly, and cumulative running totals were examined relative to time in months or total catheter-days. Because August 2010 represented the first month that simulation-trained residents rotated in the ICU, linear regression models of the running totals were obtained for each period before