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Electronic health record solutions to reduce central line-associated bloodstream infections by enhancing documentation of central line insertion practices, line days, and daily line necessity

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Background: Central line-associated bloodstream infections (CLABSIs) continue to cause preventable morbidity and mortality, but methods for tracking and ensuring consistency of CLABSI-prevention activities remain underdeveloped.

Methods: We created an integrated electronic health record solution to prompt sterile central venous catheter (CVC) insertion, CVC tracking, and timely line removal. The system embedded central line insertion practices (CLIP) elements in inserter procedure notes, captured line days and new lines, matching each with its CLIP form and feeding back compliance, and enforced daily documentation of line necessity in physician progress notes. We examined changes in CLIP compliance and form submission, number of new line insertions captured, and necessary documentation.

Results: Standard reporting of CLIP compliance, which measures compliance per CLIP form received, artificially inflated CLIP compliance relative to compliance measured using CVC placements as the denominator; for example, 99% per CLIP form versus 55% per CVC placement. This system established a higher threshold for CLIP compliance using this denominator. Identification of CVCs increased 35%, resulting in a decrease in CLABSI rates. The system also facilitated full compliance with daily documentation of line necessity.

Conclusions: Integrated electronic health records systems can help realize the full benefit of CLABSI prevention strategies by promoting, tracking, and raising the standard for best practices behavior.

Major national efforts have resulted in a large reduction in central line-associated bloodstream infections (CLABSI). Nevertheless, CLABSI continue to cause preventable morbidity and mortality[1] in 15,600 inpatients annually in acute care hospitals.[2] Successful strategies to reduce CLABSI have included ensuring sterile processes for central venous catheter (CVC) insertion, establishing maintenance and access protocols, and promoting line removal. These activities are considered gold standard care for CVCs.[3,4] However, methods for tracking and ensuring consistency of these activities are not well developed.

One method to ensure appropriate insertion processes to prevent CLABSI is the use of checklists.[5] The central line insertion practices (CLIP) checklist form was developed by the Centers for Diseases Control and Prevention to confirm appropriate hand hygiene, skin preparation with a chlorhexidine product, and maximal sterile barrier precautions.[6] The states of California[7] and New Hampshire[8] have mandated public reporting of compliance with this form. Despite the benefits of the CLIP form, inserters (or an observer) often fail to submit it, making comprehensive assessment of insertion techniques difficult.

Another method of preventing CLABSI is to monitor and feed- back CLABSI rates at the unit or hospital level to highlight good performance and encourage poor performers to improve.[9] Monitoring requires the accurate capture of the number of central line days as the denominator for rates. Often a manual or periodic sampling technique is used in place of a true count of central line days, which may contribute to inaccuracy in reported rates.

A third way to reduce CLABSI is to ensure prompt line removal. To this end, California law[10] requires that physicians document the necessity for continuing a CVC each day. As with the CLIP form, daily documentation of line necessity requires initiative on the part of the attending physician to complete the form. Given the intensity of medical care frequently required in patients needing central lines, this documentation is often not prioritized and adherence with daily documentation of necessity is poor.

Techniques that rely on clinician initiative to complete CVC- related infection prevention documentation have limited success. When good intentions fail, electronic tools can be very helpful in prompting best practice behaviors. We describe the successful use of electronic health record (EHR) solutions to improve CLIP documentation, capture CVC line days, and ensure documentation of daily necessity assessment.

METHODS

CLIP documentation

In response to the California mandate to ensure CLIP form documentation, we created a progression of documentation tools leading up to our ultimate EHR solution. For rapid deployment, we initially created a paper-based form that had to be printed, completed, and faxed by the submitter (eg, inserter or observer) to the hospital's Epidemiology and Infection Prevention (EIP) program, and then manually entered into a database by EIP staff. To improve compliance, we temporarily placed an electronic version of the CLIP form within the nursing electronic documentation system to be completed online by nurses after witnessing or assisting with a CVC insertion. During this second phase of electronic nursing documentation we no longer accepted paper CLIP forms.

Our permanent EHR solution created an electronic procedure note with embedded CLIP form elements for documenting CVC insertion. The form provided a series of check boxes (Fig 1A) that generate a narrative procedure note using templated language that could be edited by the physician before being finalized (Fig 1B). This allowed physicians to complete the note rapidly and, if necessary, remotely. To finalize the note, inserters were required to report adherence with CLIP elements using additional check boxes. Inserters could select a single check box to confirm that all elements of maximal sterile precautions were employed or select from a series of individual elements.

To evaluate the fraction of CVC insertions for which CLIP forms were completed, we identified the total number of CLIP forms received divided by the number of CVC insertions based on electronic nursing documentation indicating the new presence of a line. Adherence with CLIP elements within the form was calculated 2 ways: by assessing the fraction of forms with adherence to all CLIP components among forms submitted and by assessing the fraction of forms with adherence to all CLIP components among lines placed.

Capture of line days and identification of new lines

Comprehensive capture of CVC line days is essential for calculation of CLABSI rates, defined as the number of CLABSI events divided by the number of device days. We calculated both the total number of line days (eg, 2 lines in 1 patient for 1 day counts as 2 line days) and the National Healthcare Safety Network (NHSN) device patient days (eg, 2 lines in 1 patient for 1 day counts as 1 line day). When not otherwise specified, the NHSN definition of 1 device day as 1 day per patient who has 1 or more lines was used.

Before the development of our EHR solution, we captured line days by requiring each unit to maintain daily paper records of all patients who had CVCs. We then moved to an interim electronic system in which nurses documented the number of patients with any CVCs for every shift. This system did not track each CVC individually, so device-specific dwell times could not be calculated.

In our permanent EHR solution, we developed comprehensive electronic nursing documentation for individual CVCs. Daily e-flowsheets were modified to collect CVC insertion site (eg, internal jugular, subclavian, antecubital, and femoral), left or right side, type of CVC (eg, peripherally inserted central catheter, tunneled/ nontunneled single or multilumen catheter, tunneled/nontunneled hemodialysis line, and vascular access port), and assessment of skin integrity as part of the nursing assessment conducted during each shift.

For newly placed CVCs, inserter name and unit of insertion were also collected, facilitating clinician-specific follow-up for missing CLIP forms. An automated report matched nursing CVC documentation of new lines and electronically submitted CLIP forms. CVC insertions without associated electronic CLIP forms were reported to the inserting unit medical director, nurse manager, and inserting clinician, as well as the EIP program.

CVC data were linked between shifts, allowing for device- specific CVC information and calculation of dwell times. This allowed us to calculate device days based on the total number of lines or based on the NHSN patient days definition. A CVC's device days were counted from the first to last calendar day that had nursing documentation for a specific CVC and attributed to the first documenting unit of the day. We then calculated unit-specific or patient- specific total monthly NHSN patient device days (maximum 1 device day per patient per day) and device use ratio (number of device days divided by number of patient days) as required for mandated re- porting. In addition to use for mandated reporting, the dwell time for each line was cascaded from nursing e-flowsheets to the physician e-progress note to ensure physician attention was drawn to long dwell times.

Daily documentation of line necessity

Before our EHR solution, physicians were expected to self- initiate documentation of CVC necessity each day in accordance with California law. To facilitate this, intensive care units used a

variety of mechanisms. In certain units, the unit clerk stamped a template for documenting CVC necessity on the patient chart for the primary team physicians to complete each day. Others incorporated documentation of daily necessity into templated paper progress notes in patient charts. No facilitating interventions were implemented for non-intensive care units.

In our EHR solution, electronic physician progress notes (e- progress note) replaced paper progress notes. Within the e-progress note for a given patient, each existing CVC from the electronic nursing flowsheet documentation was automatically cascaded into the e-progress note with an indication of the CVC type, side, and site, and device-specific dwell time. Next to each listed CVC were templated options (device is needed/not needed) to confirm the necessity of each CVC (Fig 2).

Any physician documenting an e-progress note would see cascaded CVC line data and have the option to document daily necessity. However, only notes written by the primary service (self-identification as primary or consulting service is required when an e-progress note is initiated) had the requirement that these fields be completed before the note could be finalized. We calculated the distribution of dwell times before and after implementation of our e-progress notes. These phases of implementation are summarized in Table 1.

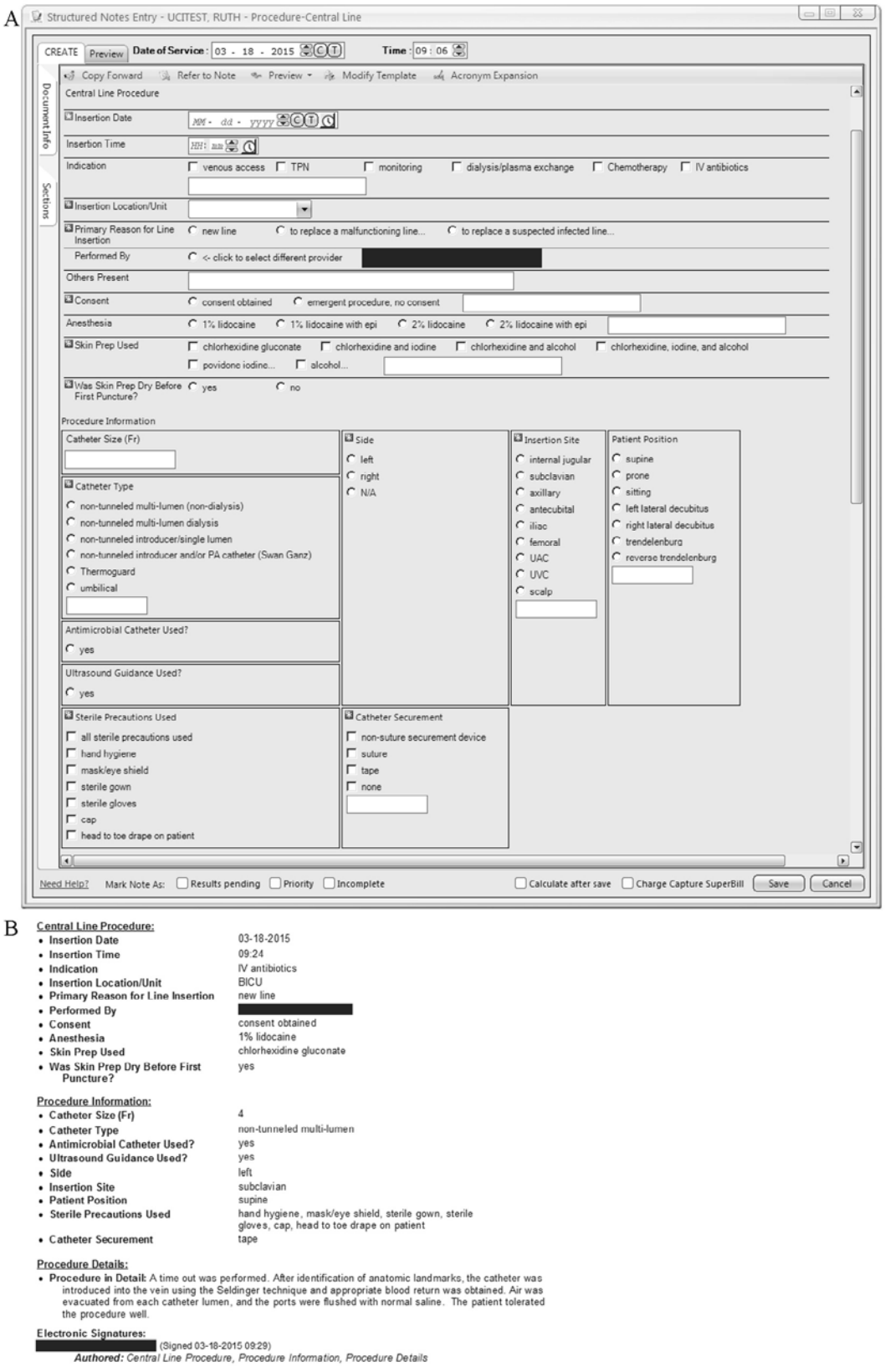

Fig 1. (A) Input elements for the electronic physician procedure note documenting insertion of a central venous catheter. Central line insertion practices (CLIP) elements are embedded into the form (bottom right) and inserters were required to report adherence or nonadherence with CLIP elements via check boxes of the individual CLIP elements. For ease of reporting, a single box was available to confirm that all elements of maximal sterile precautions were used. (B) The narrative procedure note that was automatically generated using the elements inputted into the electronic physician procedure form shown in Figure 1A. Following completion of the procedure form, documentation of the procedure was generated with templated language. This note could be generated at the bedside or remotely and could then be edited by the physician before being finalized.

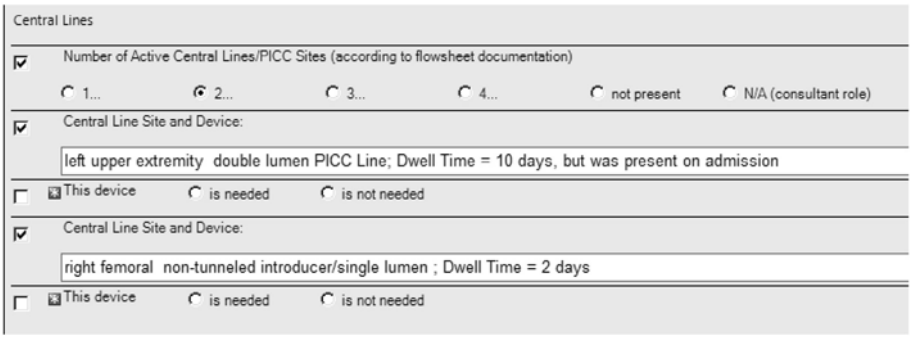

Fig 2. The elements of daily documentation of necessity that were found in all physician note templates in the electronic health record. Data on each central line were cascaded into the note from the daily nursing documentation record, including body location and line type. Dwell time was automatically calculated. Physician notes created by the primary team were required to indicate whether each line was still needed before the daily progress note could be finalized, ensuring compliance with daily documentation of necessity. All created physician notes required the user to indicate whether they represented the primary or consulting team.

Table 1

Phases of increased electronic capture of central line insertion practices (CLIP) form compliance and central venous catheter (CVC) line days

Phase 1: Paper documentation (2006-October 2011)
. Paper nursing flowsheets indicate new CVCs
. Observer (nurse)-submitted paper CLIP form
. Unknown total number of CVC insertions
. Unable to facilitate coordinated feedback
Phase 2: Nonintegrated e-documentation (November 2011-October 2012)
. Electronic nursing capture of CVC days
. Electronic CLIP form available in nursing documentation for observer (nurse) submission
. Manual process for matching newly-inserted CVCs with CLIP forms
. Unable to facilitate coordinated feedback
Phase 3: Integrated e-documentation (November 2012-present)
. Electronic health record-based e-nursing flowsheet capture of individual lines*
. Electronic health record-based inserter e-procedure note with imbedded CLIP components
. Automated process to match new CVC with CLIP form
. Automated process to coordinate feedback

*The ability to track individual lines in the phase 3 integrated e-documentation allowed us to also track CLIP documentation, daily documentation of necessity, and dwell time for each individual line.

RESULTS

CLIP documentation

Following the state mandate for CLIP form documentation for each CVC placement and before the design and implementation of our present EHR solution, physicians did not routinely include CLIP form components in their procedure notes for CVC insertion and compliance with the CLIP

form was near zero. The institution of a paper form to be completed and faxed by physicians or observers marginally improved compliance. The subsequent interim solution shifted the responsibility to nurse observers using an electronic nursing CLIP form as part of nursing documentation and in- creased CLIP form submission to 56% (Table 2). Although nurses accepted the interim partnership to complete CLIP forms, it was uniformly believed that the CLIP form should be completed by the inserter of the CVC.

Following the implementation of the permanent EHR solution based on integrated data from electronic nursing documentation and physician procedure notes, CLIP form submission significantly increased from 56%-77% (χ^2 $P < .001$) (Table 2). To verify that physician self-assessment would continue to document compliance appropriately, we evaluated compliance using both physician self- assessment and nurse observer assessment during a 2-month study period. During this evaluation, we found no differences in documentation of compliance. Under both electronic documentation systems, compliance differed based on whether percent compliance was calculated using the total number of CVC insertions (including those missing CLIP forms as noncompliant) or counting only CVC insertions for which CLIP forms were submitted (Table 2). Periods for which no data are reported were transition times during which new EHR implementation phases were being rolled out. Before the implementation of our interim electronic documentation system, our 12-month average CLABSI rate per 1,000 line days was 1.75, before the beginning of our permanent system it was 0.98, and as of December 2014, it was 0.36.

Capture of line days and identification of new lines

Our EHR solution for CVC documentation in daily nursing flowsheets increased identification of CVCs from approximately 2,117-2,982 line days per month (35% increase) (Table 3). Validation of our electronic system confirmed that capture of line days is improved using this system. Annual device use per 1,000 patient days increased from 0.26-0.30. The tracking system also allowed for more accurate capture of line days by allowing de-duplication of lines in a single patient.

The EHR solution also allowed automatic calculation of dwell times. The number of lines was 5,250 in 2013 and 5,501 in 2014. The mean dwell time was 7.00 ± 6.70 days (SD) in 2013 and 7.26 ±
7.29 days (SD) in 2014. For both years, the median dwell time was
5 days (interquartile range, 3-9 days).

Daily documentation of line necessity

Nonelectronic efforts to prompt documentation of daily necessity of CVCs, such as physician self-initiation and the stamped template, were largely unsuccessful. Only on the few intensive care units where physicians routinely used a standardized, fixed- template paper progress note was the form generally completed. In contrast, the e-progress note led to near 100% documentation of daily necessity. The only reason that daily necessity would not have been documented was if the primary service did not write a progress note for a particular day.

Table 2

Central line insertion practices (CLIP) form submission and compliance over phases of electronic health record implementation*

Implementation phase	Submission of CLIP forms	% CLIP-compliant forms (Denominator = Forms Submitted)	CLIP-compliant CVC Insertions (Denominator =CVCs Inserted)
Paper documentation			
2010, 12 mo	Unknown	99 (2,821/2,838)	
Nonintegrated electronic documentation			
November 2011-October 2012, 12 mo	55 (1,600/2,895)	56 (1,613/2,895)	99 (1,600/1,613)
Integrated electronic documentation			
January 2013-December 2013, 12 mo	77 (3,086/4,008)	99 (3,070/3,086)	77 (3,070/4,008)
January 2014-December 2014, 12 mo	84 (3,124/3,698)	100 (3,118/3,124)	84 (3,118/3,698)

NOTE. Values are presented as % (n/total sample).

*Includes CLIP-compliance for inpatient and outpatient CVC insertions.

Table 3

Average central venous catheter (CVC) device days and average device utilization per month*

CVC documentation implementation phase	Average National Healthcare Safety Network device inpatient days per month	Average number of total line days per month	Average DUR per month	Ability to track CVC-specific dwell times
Paper (2010)	2,217	Unknown	0.26 (2,117/8,617)	No
Nonintegrated electronic (November 2011-October 2012)	2,449	Unknown	0.25 (2,449/9,628)	No
Integrated electronic nursing flowsheet (2013-2014)	2,982	3,196	0.30 (2,982/9,858)	Yes

*National Healthcare Safety Network device inpatient days and number of total line days

are calculated for inpatients only.

DISCUSSION

We show that integrated EHR solutions can be instrumental in improving physician adherence to mandatory CLIP form documentation, consistent capture of central line days for the purpose of determining CLABSI rates, and daily documentation of CVC necessity. Our EHR solutions achieved success for 3 main reasons: they were imbedded into usual care, required completion, and gave feed- back. The system increased the accuracy of NHSN CVC line day capture, which decreased CLABSI rates. Most importantly, it changed and improved our metric for insertion practices compliance.

Our EHR system was built within electronic daily nursing and physician documentation to streamline workflow. The capture of line days was built into the electronic nursing flowsheet assessments, thereby being incorporated into a daily practice activity. By creating an electronic physician procedure note for CVC insertion, we incentivized use by ensuring a process that was more rapid, consistent, and comprehensive than a handwritten paper note. We further incentivized use by creating a process where physicians could easily document a procedure at a time and location separate from the patient's bedside paper chart. By embedding the CLIP elements into this preferred documentation platform, we were able to enforce documentation. Similarly, by creating an e-progress note that replaced a paper-based documentation system, we were able to cascade data to allow rapid assessment of the CVCs present in a patient and highlight the dwell time for a physician while they were documenting their daily note. This provided both a ready opportunity for easy documentation using check boxes and drop-down menu selections for the most common reasons for persistent need of a CVC.

The system achieved a high rate of use by forcing documentation of CLABSI-prevention activities. The procedure note could not be submitted without CLIP elements nor could the e-progress note be submitted without daily documentation of necessity for each CVC for a primary service note. This improved physician adherence to completion of CLIP forms.

The EHR solutions were also successful because of feedback. The CLIP elements in the procedure note reminded physicians of the proper protocols for decreasing infections. The system gave an error message if doctors or nurses tried to submit forms without answering required elements. The system also automatically calculated dwell time to alert physicians to long-dwelling CVCs that might require heightened attentiveness to skin integrity or removal. Finally, the capture of line days from nursing flowsheets allowed our EIP program to calculate and feedback accurate CLABSI rates to clinical areas. Our 35% increase in the capture of line days increased the denominator in our CLABSI rate calculation, which resulted in a 26% decrease in our calculated CLABSI rate following de-duplication of lines in a single patient.

Finally, our EHR solution allowed us to make a very important change to our metric for CLIP compliance. The current standard for measuring CLIP compliance is to calculate the percentage of all CLIP forms submitted on which use of all CLIP elements is documented. Whereas we previously calculated CLIP compliance only for CVC insertions for which we had a CLIP form according to that standard, we were now able to determine compliance for all CVC insertions. This allowed us to more accurately determine whether CVC insertions were compliant with required insertion practices and to associate changes in insertion practices with CLABSI rates.

This study is limited by use of data from a single medical center, which may not be generalizable to

other hospitals. Our system itself is limited in that it could only be used by organizations that use an EHR, and not all EHRs have the capacity to allow for the addition of these features. However, EHR capabilities are rapidly increasing across all US hospitals due to meaningful use requirements. Although we saw a reduction in the CLABSI rate during the implementation of our EHR solution, we took a multimodal this was 1 component—to address CLABSI. In analyzing the results of implementing our system, we are limited by the lack of data for the total number of CVC insertions during phase 1, before the implementation of our electronic system. This means we cannot compare the percentage of CVC insertions for which CLIP forms were submitted or the CLIP-compliance for all CVC insertions (not just those with submitted CLIP forms) between 2010 and 2011-2014.

Our EHR solution represents a novel way to address challenges to physician documentation when their processes and practices are not necessarily uniform or standardized on a day-to-day basis. Using this system, we improved documentation of CLIP, increased accuracy in calculation of CLABSI rates, and ensured documentation of line necessity, all steps toward decreasing central line infections.

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