American Journal of Infection Control ■■ (2017) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

AJIC American Journal of Infection Control

Major Article

Improving central line maintenance to reduce central line-associated bloodstream infections

Frank A. Drews PhD [a,b,*], Jonathan Z. Bakdash PhD [a], Jeremy R. Gleed MS [a]

[a] Salt Lake Informatics, Decision Enhancement, and Surveillance Center, VA Medical Center, Salt Lake City, UT
[b] Department of Psychology, University of Utah, Salt Lake City, UT

Key Words:
Human factors
Hospital acquired infections

Objective: A human factors engineering-based intervention aimed at the modification of task behavior to increase adherence to best practices and the reduction of central line-associated bloodstream infections (CLABSI). The hypothesis was tested that a central line maintenance kit would improve adherence and reduce CLABSI compared with a standard, nonkit-based method of performing central line maintenance.
Design: The study design was a 29-month prospective, interventional, nonrandomized, observational, and clinical research study using a pre–post implementation assessment.
Setting: The study was conducted at a tertiary hospital in the southwestern United States, with participants recruited from a total of 6 patient units (including intensive care units and general wards).
Participants: A total of 95 nurses and 151 patients volunteered to participate in the study.
Intervention: A central line maintenance kit was developed that incorporated human factors engineering design principles. This kit was implemented hospitalwide during the clinical study to assess the intervention's influence on protocol adherence and clinical outcomes compared with a preimplementation control condition (no kit use).
Results: The results of this clinical observations study suggest that a human factors engineering-based kit improved adherence to best practices during central line maintenance. In addition, the number of CLABSIs was significantly reduced during the postimplementation period.
Conclusions: The application of human factors engineering design principles in the development of medical kits can improve protocol adherence and clinical outcomes.

Hospital-acquired infections (HAIs) are among the leading causes of morbidity and mortality in hospitalized patients.[1] HAIs affect more than 2 million patients annually and result in an estimated 90,000 deaths per year in the United States.[2]

Bloodstream infections account for approximately 15% of all HAIs.[3] A central line-associated bloodstream infection (CLABSI) is a systemic infection caused by the accumulation of pathogens at or around the central line.[4] Up to 250,000 patients develop a CLABSI annually in the United States, resulting in as many as 60,000 patient deaths.[5] CLABSIs lead to an excess average hospital stay of approximately 7 days, are associated with a mortality rate ranging from 4%-20%, and result in additional health care costs of approximately $45,685 per patient.[6]

To address this problem, 2 complementary strategies are available, with different foci: central line insertion practices and central line maintenance (CLM) practices. A significant amount of work has focused on strategies related to the practice of central line insertions to reduce CLABSIs. For example, the Institute for Healthcare Improvement recommends the introduction of "bundles" that include 5 best practices:[7]

- Aseptic technique,
- Hand hygiene,
- Skin disinfection,
- Antimicrobial bandage, and
- Catheter hub disinfection.[8]

* Address correspondence to Frank A. Drews, PhD, Department of Psychology, 380 S 1530 E, Rm 502, Salt Lake City, UT 84112.
E-mail address: drews@psych.utah.edu (F.A. Drews).

FAD has received a grant from the VA National Center for Patient Safety.
This work was funded by a grant to the Center for Human Factors in Patient Safety from the VA National Center for Patient Safety. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the US Army Research Laboratory, Department of Veterans Affairs, or the US government. This material is the result of work supported with resources and the use of facilities at the Salt Lake City VA Medical Center.
Conflicts of interest: None to report.

0196-6553/Published by Elsevier Inc. on behalf of Association for Professionals in Infection Control and Epidemiology, Inc.
http://dx.doi.org/10.1016/j.ajic.2017.05.017

Unfortunately, adherence to medical best practices is still relatively low, ranging from 30%-50%.[9] This raises the question of how to improve adherence. Behavioral interventions to reduce CLABSI rates include feedback regarding success and measuring bundle component adherence.[10] Other evidence suggests that active educational interventions for clinicians are effective at reducing CLABSI rates. In some studies, educational interventions were combined with the use of checklists,[11] whereas other work combined the use of checklists and forcing functions.[12] Written checklists have been advocated as the solution for monitoring adherence, increasing compliance, and reducing errors in health care.[13] However, recent research indicates that using checklists does not always lead to improvements.[14,15]

Central line maintenance

Whereas previous work to reduce CLABSI focused on central line insertions, it is well established that correctly performed CLM reduces the CLABSI risk to patients significantly.[8,16] The focus of this research is on improving CLM practices using a human factors approach.

Procedurally, CLM involves antiseptic cleaning of the catheter and insertion site and replacing components where pathogens may accumulate. Although it is conceptually possible to distinguish between CLM practices and hub maintenance, in this article we treat them as part of the CLM task. Typically, CLM involves 15 individual steps (28 steps when including substeps). However, guidance on how to sequence or to perform this task is missing. Consequentially, CLABSI rates are nearly 3 times higher when inexperienced providers perform the majority of central line care.[17] Other evidence indicates that there is an association between omitted and/or suboptimally performed steps and an increase in infection risk.[8,16] CLABSI risk is 5 times greater with inappropriate central line care compared with appropriate care.[18] Conversely, appropriate aseptic technique for CLM reduced infection rates by more than 70%.[19]

Previous work indicates that in addition to central line insertions, maintenance-related activities contribute to CLABSI.[8] However, the approaches that have been applied to reduce CLABSI have yet to include improved equipment that incorporates human factors engineering (HFE) principles.

Nonadherence and checklists

Performance breakdowns have been analyzed by human factors engineers in several critical contexts, such as aviation, nuclear power, and health care, with breakdowns identified as the result of human error and procedural violations. A procedural violation or nonadherence can be defined as a deviation from a safe operating procedure, standard, or rule that is deliberate but nonmalevolent.

Williams[20] articulated the need to focus on external violation producing conditions that increase the incidence of violations. Croskerry and Chisholm[21] applied the concept of violation producing conditions to the health care setting, as did Patterson.[22]

Checklists are a popular cognitive aid to address protocol nonadherence. However, there are limitations associated with checklists:

- Omissions: Checklist factors increase the likelihood of an omission such as task sequence, memory load, and item conspicuity.
- Dual-tasking: Checklist use introduces an additional task requiring attention to be divided from the primary task.
- Checklist fatigue: Profuse checklist use can lead to a decrease in compliance because users may develop a negative attitude toward checklists.

Although traditional approaches and checklists have had some success, in their current form they provide only partial defense against nonadherence because they do not comprehensively address the capabilities and limitations of health care providers, the error and violation producing conditions in health care,[23] and the sociocultural context of health care delivery.[14,24] Thus, by ignoring some of these systemic behavior-shaping factors, previous attempts to improve adherence have been limited.

The present study examined the influence of an HFE-based implementation[25] that focused on these behavior-shaping factors with the goal to decrease CLABSI rates and increase adherence to best practices. Thus, the hypothesis guiding this work is that by introducing a CLM kit, adherence to best practices (ie, aseptic technique, correct hand sanitization, chlorhexidine gluconate [CHG] skin disinfection scrub, antimicrobial bandage application, and catheter hub disinfection) and patient safety (as measured by CLABSI rates) can be improved[25] by increasing standardization and reducing variability.[26]

In the iterative design process of the new CLM kit, the HFE principles listed in Table 1 were implemented, and continuous user feedback was collected during each design iteration. A total of 4 design iterations were performed until the kit was clinically evaluated.

METHODS

Design

This was a prospective, interventional, nonrandomized 29-month research study. This study was approved by the local institutional review board.

Setting

Data were collected in a metropolitan, university-affiliated tertiary care referral, 121 bed hospital in the southwestern United States.

Participants

Nurses

Nurses who regularly performed CLM were approached and invited to voluntarily participate (n = 95). Participants provided informed consent to be observed while performing CLM over the course of the study. Clinical qualifications of the participants were student nurse technicians (n = 4), student nurses (n = 22), registered nurses (n = 68), and not reported (n = 1). Nursing experience ranged from 0-32 years (mean experience, 6.7 years) and the number of central line-related procedures previously performed ranged from 0 to more than 1,000, with 66% of clinicians having performed <100 CLM procedures. Nurses were recruited from 6 patient care units (eg, surgical intensive care unit, medical intensive care unit, and telemetry unit).

Patients

Adult patients in the participating patient care units who required CLM were invited to participate. Participants (n = 151) provided informed consent to be observed during the CLM procedure.

Apparatus and materials

In the baseline condition, CLM required nurses to collect 26 unique items (38 items in total) from the supply room. One possible consequence of the manual collection of materials is omission of items. For example, using an estimated omission rate of 1% per unique item, the overall likelihood of omitting at least 1 item equals $P = .32$.