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Usability and impact of a computerized clinical decision support intervention designed to reduce urinary catheter utilization and catheter-associated urinary tract infections

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Abstract

Objective—To evaluate the usability and effectiveness of a computerized clinical decision support (CDS) intervention aimed at reducing the duration of urinary tract catheterizations.

Design—Retrospective cohort study.

Setting—Academic healthcare system.

Patients—All adult patients admitted from March 2009 through May 2012.

Intervention—A CDS intervention was integrated into a commercial electronic health record. Providers were prompted at order entry to specify the indication for urinary catheter insertion. Based on the indication chosen, providers were alerted to reassess the need for the urinary catheter

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if it was not removed within the recommended time. Three time periods were examined: baseline, after implementation of the first intervention (stock reminder), and after a second iteration (homegrown reminder). The primary endpoint was the usability of the intervention as measured by the proportion of reminders through which providers submitted a remove urinary catheter order. Secondary endpoints were the urinary catheter utilization ratio and the rate of hospital-acquired CAUTIs.

Results—The first intervention displayed limited usability with 2% of reminders resulting in a remove order. Usability improved to 15% with the revised reminder. The catheter utilization ratio declined over the three time periods (0.22, 0.20 and 0.19, respectively, p -value <0.001), as did CAUTI per 1,000 patient days (0.84, 0.70, 0.51, respectively, p -value <0.001).

Conclusions—A urinary catheter removal reminder system was successfully integrated within a healthcare system's EHR. The usability of the reminder was highly dependent on its user interface, with a homegrown version of the reminder resulting in higher impact than a stock reminder.

BACKGROUND

Urinary tract infections (UTIs) are the most common type of healthcare-associated infection. Virtually all healthcare-associated UTIs are caused by instrumentation of the urinary tract. Catheter-associated urinary tract infections (CAUTI) have been associated with increased morbidity, mortality, hospital cost, and length of stay.^{1–4} Catheterization can be an essential part of patient care. However in many cases catheters are placed for inappropriate indications and healthcare providers are often unaware that their patients have catheters, leading to prolonged and unnecessary use.⁵

Several studies have focused on strategies to limit the use and duration of urinary catheters in an effort to decrease CAUTI rates. The most effective strategies described are reminder systems to reassess the need for a urinary catheter.^{6,7} The majority of reminder systems studied to date have used non-computerized reminders such as written reminders,^{2,8–10} stickers,¹¹ pre-written orders,¹² and nurse-generated reminders.^{13–16}

In a recent review of the literature examining reminder systems aimed at improving the appropriate use of urinary catheters,⁶ only one study examined the use of computerized decision support (CDS) interventions. In this study the intervention group had increased documentation of catheterization and decreased catheter duration.¹⁷ However, the study had a number of limitations, including (1) a small sample size, (2) a short study period, and (3) physicians in the intervention arm did not have to use the CDS intervention but could instead have used written orders.

A substantial body of evidence suggests that CDS interventions may be an efficient and cost-effective way of leveraging the electronic health record (EHR) to obtain sustainable improvements in patient care quality.¹⁸ However, developing effective decision support interventions represents a significant challenge. A key requirement for an effective CDS intervention is integration into clinical workflow¹⁹ and human factors principles play essential roles in the success of any CDS intervention.^{20–22} CDS interventions thus often fall

short of delivering their full potential benefit because their human interfaces are not optimally designed for efficient interactions.

We hypothesized that a computer-based order for inserting an indwelling urinary catheter, combined with computer-generated reminders to remove the catheter, would remind providers that the catheter was in place and encourage catheter removal when it was no longer required. In this study, we examined the usability of a computerized CDS intervention integrated into a commercial electronic health record (EHR) serving all inpatients in a multi-hospital academic healthcare system as well as the effects of the intervention on urinary catheter utilization and rates of CAUTI. We focused on usability of the CDS to ensure that the full potential benefits of the intervention could be achieved and to emphasize the importance of usability metrics in evaluating CDS systems.

METHODS

Developing and implementing the intervention

In an effort to prevent CAUTIs locally and nationally, the evidence-based practice center (EBPC)^{23,24} in our institution collaborated with the Healthcare Infection Control Practices Advisory Committee (HICPAC)²⁵ of the Centers for Disease Control and Prevention (CDC) to update the national guideline for prevention of CAUTIs.²⁶ The guideline was released in 2009.²⁷ The first of three “Priority Recommendations” focused on “Appropriate Urinary Catheter Use” recommending that providers insert catheters only for appropriate indications and leave them in place for only as long as needed. The EBPC then worked locally with a multidisciplinary team to integrate the guideline recommendations into clinical care through the following computerized CDS interventions.

Phase I: In March 2010, we created a new urinary catheter order that prompted providers at order entry to specify the indication for urinary catheter placement (Table 1). These indications were modeled on the CDC guideline and available in an easy-to-select drop down menu. Based on the indication chosen, the provider was then alerted to reassess the need for the urinary catheter if it was not removed within the recommended time period. Our initial provider reminders were developed using commercially available (i.e. stock) reminders from our EHR vendor (Figure 1) and were displayed when a non-pharmaceutical order was placed. A provider could then proceed past the reminder if the provider decided to keep the urinary catheter in place. In that case, the provider would subsequently receive a daily reminder to reassess the need for the catheter. Alternatively, the provider could choose to remove the urinary catheter through an order embedded in the initial reminder. After implementation, we evaluated the number of “catheter removal” orders that were placed through the reminder. Preliminary analyses revealed a low rate of removal orders placed through the reminder. Discussion with our multidisciplinary group as well as users suggested that a primary reason for the low rate of removal through the reminder was the non-intuitive nature of the reminder interface.

Phase II: We removed the stock reminder and implemented a new homegrown reminder in February 2011 to simplify the placement of a urinary catheter removal order. The revised reminder (Figure 2) is displayed when the order entry icon is clicked for any type of order,

before order entry is performed. This design was thought to be less disruptive than alternatives, because reminders related to the urinary catheter would not be confused with reminders related to the other orders being placed by the providers. With the revised reminder, the provider simply needed to respond “YES” or “NO”. When the “YES” button is selected, a “Remove Urinary Catheter” order is placed. When the “NO” button is selected, one proceeds without placing a “Remove Urinary Catheter” order. The reminder is subsequently displayed every 24 hours until the catheter is removed or the indication for the catheter is changed. This revised reminder required two mouse clicks to submit a “Remove Urinary Catheter” order compared to the seven mouse clicks required by the initial reminder. Further comparison and screenshots of the initial and revised reminder can be found in the supplementary appendix.

In May 2011, three months after the start of phase II, the CDS intervention was further refined through the addition of a mandatory urinary catheter assessment in the standard hospital admission order set. The goal of this intervention was to improve documentation of catheters and ensure that all patients being admitted with a urinary catheter are documented as such.

Setting

The CDS intervention was developed, implemented and examined in a quaternary care academic healthcare system comprised of three acute care teaching hospitals with a combined capacity of over 1,600 beds and 75,000 annual admissions. These three hospitals include 62 hospital units (30 units in hospital A, 20 in Hospital B and 12 in Hospital C). For the purposes of this study, hospital units were characterized as Medical, Surgical, Critical Care, Women’s Health, or Mixed units. All Hospitals within the health care system currently use Sunrise Clinical Manager version 5.5 (Allscripts, Chicago, Illinois, USA) as their EHR.

Source population

The study sample included all adult inpatient admissions (18 years and older) to one of the three hospitals in the healthcare system during the study period. Admissions to the short procedure units, emergency room, rehabilitation units, and hospice units were excluded from the study sample.

The first study period included admissions in the 12 months prior to the first version of the CDS intervention (March 2009 to February 2010); the second period included admissions between the first and revised versions of the CDS intervention (March 2010 to January 2011); the third period included admissions in the 16 months following the implementation of the revised CDS intervention (February 2011 to May 2012).

The study received expedited approval and a HIPAA waiver from the University of Pennsylvania Institutional Review Board.

Primary and secondary outcomes measures

The primary outcome measure of this study was the CDS utilization and usability measure of the proportion of reminders for which a urinary catheter removal order was placed within

10 minutes of the alert firing. The proportion of positive responses to computerized CDS interventions has been shown to be a simple and powerful method of tracking and evaluating the impact of a CDS intervention.^{21,28}

The secondary outcome measures were three urinary catheter process and outcome measures: the number of urinary catheter days per 1,000 patient days (i.e. catheter utilization ratio), number of CAUTIs per 1,000 catheter days (CAUTI rate using the CDC National Healthcare Safety Network methodology²⁹), and the number of CAUTIs per 1,000 patient days (population CAUTI rate^{30,31}).

These secondary data are collected daily by unit-level managers, aggregated at the unit level, and entered on a monthly basis into a proprietary infection-control software package used by all three hospitals in the healthcare system (Theradoc, Hospira Inc., Salt Lake City, Utah, USA). The data are collected and maintained by infection control staff and reported to the National Healthcare Safety Network (NHSN)³² regularly. As such, our definitions for CAUTI will be consistent with those of NHSN as released in January 2009.³³

For the secondary outcome measures, data were not available for the first 8 months of the study time period for Hospital “B” as the Theradoc infection-control system had not yet been instituted in this hospital at that time. We thus performed sensitivity analysis of the secondary outcomes, analyzing these outcomes by hospital. No effort was made to impute the missing data.

Statistical methods

Demographic and clinical characteristics of the patients in the study cohort were summarized using standard descriptive statistics and were compared across the three study time periods (no reminder, initial reminder, revised reminder). Categorical data were analyzed using the chi-squared statistic. For continuous variables whose distributions approximated normality, analysis of variance (ANOVA) was used for comparisons. When normality assumptions were not satisfied, the non-parametric Kruskal-Wallis test was utilized.

A pre-post analytic approach was used to assess the impact of the CDS intervention. The pre-post analysis compared aggregated rates between the three intervention phases. To determine statistical significance, the outcomes were modeled using a categorical “intervention” predictor variable in univariate regression models. The usability (proportion of ‘remove’ response out of all reminders) and process measures (catheter days per 1,000 patient days) were modeled using linear regression. The outcome measures (CAUTI per 1,000 catheter days and CAUTI per 1,000 patient days) were modeled using Poisson regression with robust standard errors.

Outcomes were also stratified by hospital and by five pre-specified hospital unit types to explore any potential interactions between hospital or unit type and the intervention.

All analyses were performed with the use of Stata 12.1 software (Stata Corp, College Station, Texas, USA).

RESULTS

Patient characteristics

The study included 222,475 inpatient admissions across our three hospitals during the study time period (March 2009 through May 2012). While there were small but statistically significant differences in the majority of the patient characteristics measured, the baseline characteristics of the patient populations across our three time periods were clinically similar (Table 2).

Usability measure

In the period after the implementation of the initial reminder, only 2% of reminders led directly to the placement of a remove urinary catheter order. This proportion increased dramatically with the implementation of the revised reminder. After the revision, approximately 15% of reminders led directly to the placement of a remove urinary catheter order. The proportion of reminders that led to a remove urinary catheter order varied significantly by hospital. At Hospital A, 10% of reminders led directly to a remove urinary catheter order, while at Hospitals B and C, 22% of reminders led to a remove urinary catheter order (Figure 3). The proportion varied by unit type with Critical Care units having the lowest proportion of reminders leading to a urinary catheter remove order and Women's Health units having the highest proportion of reminders that led to a remove urinary catheter order (Table 4).

Process and outcome measures

The process measure of catheter utilization (urinary catheter days per 1,000 patient days) decreased during all three time periods for the healthcare system as a whole. The decline was statistically significant in Hospitals A and C. The outcome measures of CAUTIs per 1,000 catheter days as well as the population CAUTI rate (CAUTIs per 1,000 patient days) declined during all three time periods for the healthcare system as a whole, but this change was driven by the declines seen in Hospital A, which was the only hospital to demonstrate a statistically significant decline in these two outcomes.

DISCUSSION

The aim of this quality improvement study was to develop and implement a CDS intervention within a commercial EHR to reduce the duration of urinary catheterization for patients admitted to a multi-hospital healthcare system. Our study highlights the importance of human factor principles²² when implementing CDS interventions. Minor changes in reminder structure can have a dramatic impact on the usability of a CDS intervention and on provider actions. In this intervention, a homegrown CDS intervention more effectively met essential human design elements compared with a stock alert leading to increased usability and acceptance of the intervention.

Many usability factors may be difficult or impractical to anticipate prior to implementation. Monitoring the impact of a CDS intervention with a simple usability metric can quickly alert the CDS team to usability issues and guide appropriate modifications to the intervention. In

the case of action-oriented reminders, usability can be captured by the proportion of positive responses to the reminder. This measure has high face validity, is easy to collect and track over time, and has high interpretability.

We found substantial variability in our usability measure when stratified by hospital or by hospital unit type. These differences are not readily interpretable but may have been driven by patient mix. Higher rates of usability were identified in units where patients have a more reliable hospital course (such as obstetrics care in the Women's Health units) and lower rates of usability were identified in units where patients have a more uncertain hospital course (such as the medical intensive care unit).

An unexpected result from this study was the curvilinear response of the usability measure over time. The proportion of reminders that led to a remove urinary catheter order rose suddenly to a high level after implementation of the revised intervention and then declined slowly to a new long-term baseline. However, intervention maturation is a common finding in quality improvement studies and one might expect provider response to change after implementation as the new intervention is integrated into existing workflow.

During the study period, both the urinary catheter process measure (urinary catheter utilization) and outcome measures (CAUTI rate) decreased significantly. Inferences regarding causality and the contribution of the CDS intervention on these improvements are limited by the nature of our study and the available data. In particular, multiple independent unit and service-based interventions aimed at preventing CAUTIs were implemented during the three-year study period. Disentangling these intervention effects from those of the CDS intervention presented here may not be feasible. However, the CDS intervention was the only healthcare system-wide intervention directed at urinary catheter rates during our study period and was a major component of efforts to increase documentation and raise awareness of urinary catheter utilization during this time period. In addition, our primary aim was to successfully integrate a CDS intervention into the clinical workflow of the healthcare system such that it would both enhance and work in conjunction with local interventions and practices.

Two strengths of our intervention warrant comment. Most reported improvement efforts have been directed at limited subpopulations located on a single hospital unit or service. However, interventions restricted to hospital units or services may have limited generalizability. This quality improvement initiative was hospital and healthcare system wide, increasing both its generalizability and potential benefit. Additionally, most prior studies have relied on a brief study period and several studies have observed an increase in catheter use when the intervention had ended.^{13,15,34} Maintenance, the extent to which an intervention program is sustained over time, is an important component of the external validity of any intervention.³⁵ The two-year follow-up period from March 2010 to May 2012 strengthens the external validity and sustainability of our findings. CDS systems integrated into the EHR may support sustainability by automating assessment and reminders, integrating easily into providers' EHR workflow, and being associated with low maintenance costs.

Our study has several limitations. First, our pre-post design may not fully account for secular changes and lacks a concurrent control group. Second, we did not assess changes in the appropriateness of urinary catheter use across our study periods. Third, the optimal proportion of reminders that leads to a positive provider response is not easily definable. The usability measure in this study is thus useful as a relative measure that enables us to compare time periods, but may have limited utility as an absolute measure. However, usability cannot easily be defined in absolute terms and measures of usability similar to the one examined in this study have proven themselves as simple but powerful aids in improving CDS interventions.^{21,28} Fourth, our process and outcome measures were based on administrative data aggregated at the hospital unit level and collected once daily. These data provided estimates of catheter days and patient days. Precise measures, beyond the daily aggregate data we used, were not available for this study. As a result, we may not have fully captured the changes in catheter utilization over the time period studied. The aggregate data used in this study may have underestimated the relative changes in catheter days and thus the effects of the CDS intervention. Fifth, our experience of implementing a CDS intervention in an academic health system may not be generalizable to smaller healthcare systems with limited EHR systems. However, the adoption of integrated EHR systems by hospitals is expected to continue at a rapid rate and become the standard of care within the near future.³⁶

In conclusion, this study demonstrated the feasibility and usability of a simple computerized CDS intervention embedded within a multi-hospital healthcare system's EHR. It also emphasized the importance of usability assessment during the implementation of any new CDS intervention. The usability of the intervention was highly dependent on its user interface, with a homegrown version of the reminder resulting in higher impact than a stock version of the reminder.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Alert Detail - TESTHUP, FOLEY1 - CBC W/Diff (Heme Profile+Elect Diff)

Alert Summary

Acknowledged	Viewed	Alert	Priority	Type	Comment	Scope
	✓	Urinary Catheter recommen	HIGH	WARNING		Chart

Alert: Urinary Catheter recommended time period has passed.

Message: Your patient has a Urinary Catheter in place for longer than the recommended time period. Please **consider entering a Remove Indwelling Urinary Catheter order** if clinically appropriate. To do so, click on **VIEW ACTIONS** below to place a **REMOVE Urinary Catheter** order.

Acknowledgement Comment:

Alert 1 of 1

To view suggested actions for the CBC W/Diff (Heme Profile+Elect Diff) order click View >

To continue with the CBC W/Diff (Heme Profile+Elect Diff) order unchanged click Proceed >

To return to the CBC W/Diff (Heme Profile+Elect Diff) order and discard alerts click Go Back >

Figure 1.

Figure 2.

Figure 3.

Table 1

Indications for Use of Indwelling Urinary Catheters

Indication	Timing of Alert
Routine postoperative use	Fires 72 hours after order placed
Patients receiving epidural anaesthesia/analgesia	Fires 72 hours after order placed
Acute urinary retention or obstruction	Fires 72 hours after order placed
Deeply sedated (obtunded due to injury, illness, or chemical induction)	Fires 72 hours after order placed
Need for accurate measurement of urinary output in critically ill patient	Fires 72 hours after order placed
Uncleared spinal radiographs (thoracic or lumbar spine, female only)	Fires 72 hours after order placed
Urological, gynecological, or perineal procedure performed	No alerts fired
Open sacral or perineal wounds in incontinent patients	No alerts fired
To improve comfort for end of life care if needed	No alerts fired
Chronic indwelling urinary catheter	No alerts fired

Table 2

Characteristics of Patients in the 3 Study Periods

Characteristic	No Reminder (N=63,616)	Initial Reminder (N=65,247)	Revised Reminder (N=93,612)	P
Age, mean, years	53.2	54.3	54.5	<0.001
Sex, female	58.2	57.1	56.8	<0.001
Race/Ethnicity				
White	56.1	53.8	53.5	<0.001
Black	38.4	40.7	40.8	
Other	5.5	5.5	5.7	
Length of stay, median (IQR), days	4 (3–7)	4 (3–7)	4 (3–7)	<0.001
DRG weight, mean (SD)	1.7 (2.09)	1.8 (2.12)	1.8 (2.07)	<0.001
Hospital				
A	58.1	50.8	50.4	<0.001
B	9.4	20.9	21.4	
C	32.5	28.2	28.2	
Discharging service				
Medicine	26.5	26.1	26.5	<0.001
Surgery	31.0	31.2	30.6	
Mixed	20.4	22.7	22.8	
Women's Health	16.8	15.3	14.9	
Critical Care	5.3	4.7	5.2	
Top 5 primary discharge diagnoses				
Diseases circulatory system	18.9	20.7	19.6	<0.001
Complications pregnancy	15.0	14.0	13.5	<0.001
Neoplasm	12.4	12.0	11.9	<0.01
Injury and poisoning	11.9	12.1	11.7	0.03
Diseases digestive system	7.8	7.8	8.2	0.01

Note. Data are % unless otherwise indicated. DRG, diagnosis-related group; IQR, interquartile range; SD, standard deviation.

Table 3

Pre-post analysis across the three study periods by hospital

Outcome	No reminder	Initial reminder	Revised reminder	P
Healthcare System				
"Remove" response out of all reminders, %	-	2.2%	15.2%	<.001
Catheter-days per 1,000 patient-days	0.22	0.20	0.19	<.001
CAUTI per 1,000 catheter-days	3.79	3.28	2.54	<.001
CAUTI per 1,000 patient-days	0.84	0.70	0.51	<.001
Hospital A				
"Remove" response out of all reminders, %	-	2.0%	10.4%	<.001
Catheter days per 1,000 patient-days	0.22	0.21	0.20	0.045
CAUTI per 1,000 catheter-days	5.21	4.45	2.92	<.001
CAUTI per 1,000 patient-days	1.12	0.93	0.60	<.001
Hospital B				
"Remove" response out of all reminders, %	-	2.0%	22.1%	<.001
Catheter-days per 1,000 patient-days	0.16	0.16	0.16	0.83
CAUTI per 1,000 catheter-days	1.20	1.35	2.38	0.76
CAUTI per 1,000 patient-days	0.21	0.24	0.42	0.14
Hospital C				
"Remove" response out of all reminders	-	2.8%	22.3%	<.001
Catheter-days per 1,000 patient days	0.23	0.21	0.19	<.001
CAUTI per 1,000 catheter days	1.17	1.76	1.70	0.63
CAUTI per 1,000 patient days	0.33	0.54	0.38	0.43

Note. Data are no., unless otherwise indicated. CAURI, catheter-associated urinary tract infection

Table 4

Pre-post analysis of usability measure across the three study periods by clinical service

Clinical Service	No Reminder	Initial Reminder	Revised Reminder
Critical Care	-	1.2	5.0
Medicine	-	1.3	21.8
Surgery	-	4.2	21.5
Women's Health	-	3.7	34.9
Mixed	-	0	26.1

Note. Data are %