Usability Evaluation and Implementation of a Health Information Technology Dashboard of Evidence-Based Quality Indicators

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Health information technology dashboards that integrate evidence-based quality indicators can efficiently and accurately display patient risk information to promote early intervention and improve overall quality of patient care. We describe the process of developing, evaluating, and implementing a dashboard designed to promote quality care through display of evidence-based quality indicators within an electronic health record. Clinician feedback was sought throughout the process. Usability evaluations were provided by three nurse pairs and one physician from medical-surgical areas. Task completion times, error rates, and ratings of system usability were collected to compare the use of quality indicators displayed on the dashboard to the indicators displayed in a conventional electronic health record across eight experimental scenarios. Participants rated the dashboard as "highly usable" following System Usability Scale (mean, 87.5 [SD, 9.6]) and Poststudy System Usability Questionnaire (mean, 1.7 [SD, 0.5]) criteria. Use of the dashboard led to reduced task completion times and error rates in comparison to the conventional electronic health record for quality indicator–related tasks. Clinician responses to the dashboard display capabilities were positive, and a multifaceted implementation plan has been used. Results suggest application of the dashboard in the care environment may lead to improved patient care.

KEY WORDS: Evidence-based practice, Health information technology, Nurse-sensitive indicators, Quality indicators, Usability

Recent estimates indicate that more than 400,000 Americans die each year of complications arising from preventable medical errors and associated adverse events.[1] This positions medical errors as the third leading cause of death in the United States.[2] The burden of preventable medical errors extends to costs estimated to total approximately $1 trillion.[3] Care providers identify fast-paced work and feelings of being overwhelmed as top contributors to errors.[4]

Health information technology (HIT) systems that provide interactive prompts and information to support clinicians during stressful situations[5–8] have been observed to improve patient safety, organizational efficiency, and speed of monitoring.[9–16] Clinical and quality "dashboards" are two forms of HIT that provide important patient care information. Clinical dashboards are designed for use by individual clinicians for surveillance and to guide practice decisions at the point of care by displaying relevant, timely, and usable data.[17] Quality dashboards demonstrate areas for practice improvement, often with retrospective data display, for administrative management of a unit or organization.[17,18]

Use of HIT's capabilities is growing rapidly. Reports of systematic development and evaluation of dashboards, however, are largely limited to addressing a single clinical issue or screening for a single disease.[19–27] The reality of hospital care is that patients rarely have a single illness or single risk that may affect quality care. Combining clinical and quality dashboards is an essential next step for improving patient care provided by interprofessional teams.[12–14] Health information technology dashboards must be well received, require little additional time, contain evidence-based recommendations, improve quality, and be integrated into clinicians' workflow, however, before creating an opportunity to affect care processes and outcomes.[17,24,25,28–30]

Complementary to HIT systems, evidence-based quality indicators provide objective measures for care providers to assess healthcare structures, processes, and outcomes.[7,31–33] For instance, Malone et al[16] developed a core set of quality indicators to promote interprofessional team planning for hospitalized older adults. The challenge, however, is how to integrate such evidence-based indicators within clinician workflow given the complexity of their clinical priorities and patient needs.[7,34] Despite the potential benefits of incorporating evidence-based clinical indicators into an HIT system,

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we are aware of few efforts to systematically develop and evaluate such systems.

Recently, Schall et al[35] developed a prototype dashboard designed to summarize and display quality indicators associated with patient risks at a large, Midwestern academic medical center. A focus group of nurse managers, physicians, and hospital quality professionals identified design criteria for the dashboard. Indicators were selected from among core quality metrics that were evidence based, used existing data not requiring additional data input by clinicians, and were associated with value-based purchasing or national standards. Pseudodata mimicking dynamic process data from a medical-surgical unit were used to simulate electronic health record (EHR) patient information and develop the application. A preliminary system usability evaluation suggested that the dashboard was "good" according to the System Usability Scale (SUS) criteria,[35–39] but with opportunity for improvement. The objective of the current study was to modify the prototype dashboard to improve upon its design and enable its function within an inpatient EHR system for interprofessional planning (ie, "rounding"). Usability testing techniques were then used to evaluate use of the EHR functional dashboard in typical clinical scenarios. This article describes the process of developing, evaluating, and implementing the EHR functional dashboard to inform others interested in the benefits of an innovative approach to healthcare delivery.

METHODS

Converting Prototype Dashboard Into Electronic Health Record Functional Dashboard

Design improvement specifications from the prototype's usability evaluation and knowledge of the existing EHR software were used to develop a list of specifications for converting the prototype into an EHR functional dashboard (Table 1). The majority of these specifications focused on methods to reduce the amount of "clutter" presented, as cluttered displays have been observed to result in substantial performance decrements.[40,41] In addition, a list of quality indicators,[42] with each indicator's relevant thresholds or scores, and data location (cell or row) within the EHR (Table 2) was specified. A query was formulated to display a list of all active inpatients in rows with data available to display in columns similar to a spreadsheet (eg, patient identifiers, room location, quality indicators). The display columns were built according to each quality indicator's unique specifications (ie, real-time scores, trending data, information on specific catheters and the patient provider). Data elements were linked from patient records using a "pointer" (ie, custom programming linking the data element within the EHR, such as clinical assessments and orders, to be displayed). A focus group of care providers reviewed and confirmed the display style of thresholds for each data element (eg, fall risk used a different scale than delirium scores), to identify elevated patient risk. A score was determined to be binary (ie, favorable or unfavorable) or ranked (acceptable/normal risk, marginal risk, elevated risk) based on evidence-based thresholds or established by clinical experts.

Table 1. Specifications for Converting Prototype to EHR Functional Dashboard

1. Ability to display real-time data from patient records
2. Ability to show data trend indicating a change in patient condition
3. Color coding to quickly indicate positive/negative scores or results to identify risks
4. Indicator thresholds that will change color display and update to current scores/status
5. Rapid calculation with automatic and frequent updating (eg, every 15 min)
6. Dynamic reporting (both unit data for nurses and physician-/provider-specific patient data)
7. Meaningful iconography
8. Indicator that will display if data are not current (out-of-date documentation)
9. Link each cell to the specific related part of the patient record (eg, provider log-in goes to medication orders; RN log-in goes to flowsheet)
10. Link dashboard display within other parts of the EHR (eg, rounding and handoff tools)
11. Consider summary reports (eg, identify all patients with a central line)

The need for customizable features, such as ability to set thresholds, lack of icon graphics for color-coding display, lack of timely automatic refresh, and space constraints, led to development of the EHR functional dashboard in the EHR's reporting module. A significant advantage of this decision was availability of icons as a substitute for display of numerical values and customization of unique thresholds for each quality indicator to both numeric and string or text values. An additional benefit was the ability to display subelements of each of the quality indicators (eg, fall risk factors used to create the risk score, list of all catheters). Users could compile and view the report at their leisure to avoid pitfalls of EHR alerts.

Development Challenges

Displaying trending data (ie, changes in patient condition) was one of the important original specifications from users.[35] However, existing EHR software did not allow display of trended data within the reporting module, leading to an alternative programming approach. Building display columns for the central venous and urinary catheters was also difficult because of charting omissions. If the catheter was not documented as discontinued upon discharge, the catheter days continued to accumulate days

Table 2. Quality Indicators and Score Thresholds Included in the EHR Functional Dashboard

Indicator	Threshold/Rating System[a]
Pain rating	Acceptable = green
	Unacceptable = red
Fall risk	<7 = green
	≥ 7 = red
Pressure ulcer risk	>18 = green
	≤18 = red
Delirium risk	<3 = green
	≥3 = red
Barthel Index/Functional status	51–90 = green
	0–50 = red
Restraint in use	Present = red
Urinary catheter days	No. of days
Central-line days	No. of days
LACE[b] score (ie, readmission risk)	<9 = green
	≥9 = red
Readmit (ie, days since last admission)	Within 90 d = yellow
	Within 30 d = red
Actual length of stay	No. of days
Expected length of stay	No. of days

[a]Green, low risk; yellow, marginal risk; red, high risk.

[b]The LACE index identifies patients who at risk of readmission or death within 30 days of discharge.[43]

to years later and appear on a subsequent admission. As an alternative (and for accurate information of catheter days), the EHR functional dashboard was programmed to display catheter days only from admission to discharge during a single inpatient stay.

Preliminary Review of EHR Functional Dashboard

Following conversion of the prototype dashboard into an EHR functional version, a focus group of nurse managers, physicians, and hospital quality professionals met again to discuss the clinical accuracy of data elements. During these meetings, care providers discussed whether the dashboard display of all inpatients would be specific enough for their needs. Physicians were concerned about having enough information on patients they were specifically "rounding on" or were cared for by their team. Nurses needed information only on patients within their units, within specific geographic proximity, or within their patient assignment. A difficulty arose making the report dynamic and exclusive to each user role, using each clinician's log-in identification. The task was to find a data element within the EHR that both groups used and that identified their roles. Both providers and nurses assign themselves to the patient's treatment team on admission or at the beginning of their shift. The functionality to identify an individual patient's care team already existed within the current system and facilitated remote communication among clinicians. A filter was added to the query using the treatment team, adding attending physician to the list of licensed independent practitioners or nurses already active on the patient's treatment team. This allowed the clinician or teams to view only patients they were responsible for treating. Use of icons and color coding was also refined at this stage to improve intuitive interpretation of threshold scores. An image of the EHR functional dashboard with patient-identifying cells collapsed is provided as Figure 1.

Electronic Health Record Functional Dashboard Evaluation

Evaluation followed refinement and integration of the EHR functional dashboard into the medical center EHR. Three pairs of nurses and one physician from medical-surgical areas volunteered to participate. This sample size has been identified as more than sufficient for usability studies.[44,45] All participants were proficient EHR users. Participants were asked to perform a series of tasks using the conventional EHR interface and new EHR functional dashboard. The tasks were selected to include commonly used evidence-based interventions for the associated quality indicator. Tasks matched practices previously implemented through the organization's quality improvement program. The order of tasks and presentation of system were both randomized to prevent training effects. Participants' interactions with these two systems were recorded through audio, screen recording, and real-time observations and annotations of usability issues using Morae (TechSmith Corporation, Okemos, MI), a usability testing platform. Institutional review board approval was sought prior to usability testing, and the protocol was determined not to be human subject research.

Procedure

Participants were provided with a list of "test" patients (with pseudo–patient records for training purposes) visible on the computer screen, using an EHR feature that is familiar and part of their usual workflow. A brief orientation to the dashboard was provided with instructions about the tasks to complete. Participants were asked to perform a series of tasks using both the dashboard and conventional EHR display (Table 3). The objective of the task-based evaluation was to assess potential differences in the time to complete a task and the percentage of tasks completed without error between the dashboard and conventional system. Participants were instructed to speak aloud as they completed tasks and maneuvered through the system. This helped gather insights on the difficulties participants encountered as they used the system. Participant pairs alternated task completion with observation and discussion.

Immediately following completion of the task-based evaluation, each of the seven participants completed a paper-based SUS and Poststudy System Usability Questionnaire (PSSUQ).[36,38,39,47] The SUS is a 10-item survey used to

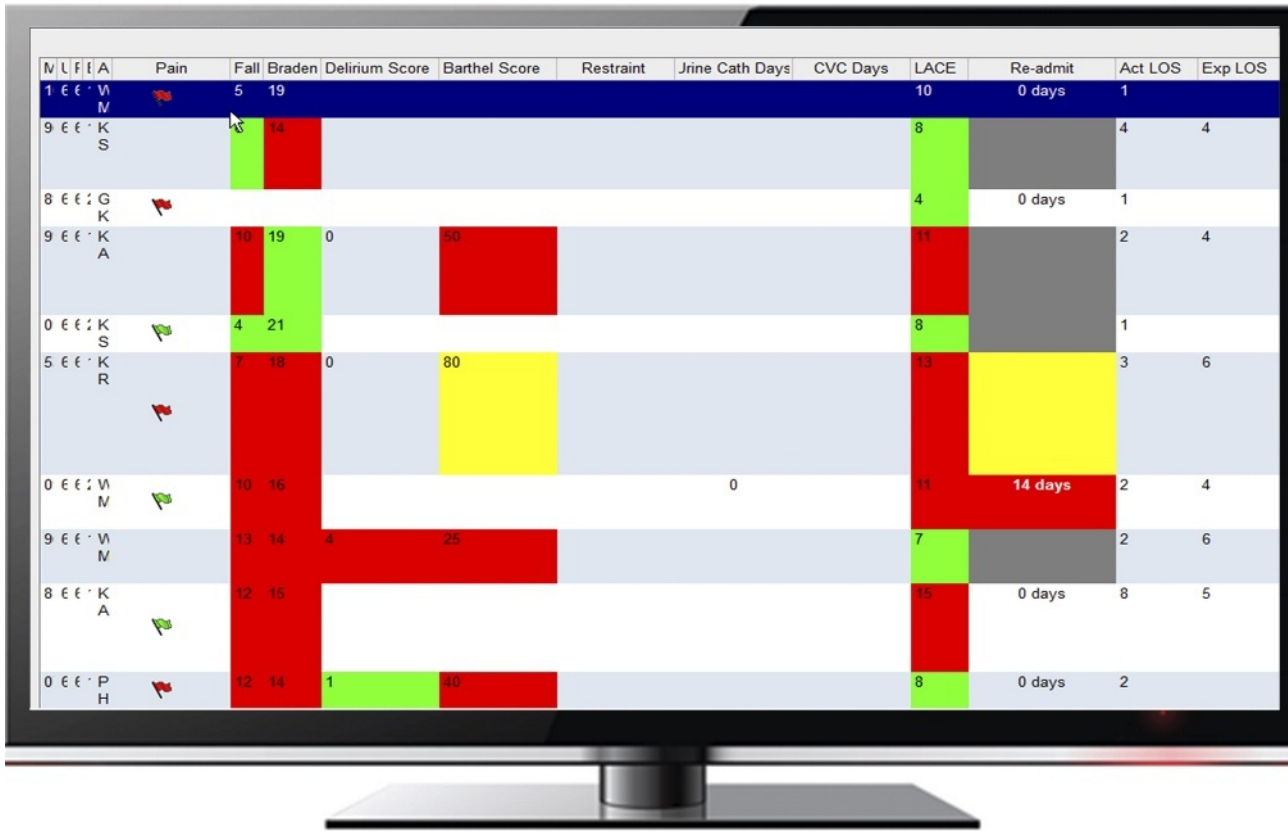

FIGURE 1. The HIT dashboard with patient-identifying information collapsed. Used with permission from Epic Systems Corporation, 2016.

evaluate an individual's assessment of a system's usability. Each item has five response options ranging from "strongly disagree" to "strongly agree." Scoring of the SUS yields a composite measure between 0 and 100 that represents the overall usability of the system being studied. While various scoring criteria have been developed, products with SUS scores greater than 85 are generally considered highly usable (ie, among the top 10% of products).[38,48] Previous work has shown that the SUS is reliable, correlates well with other usability scales, and is a useful metric for overall product usability.[49,50] The PSSUQ consists of 19 items that measures users' perceived satisfaction with a product. Factor analysis of the PSSUQ has indicated an overall satisfaction scale (average of responses to Items 1–19) and three subscales: system usefulness (Items 1–8), information quality (Items 9–15), and interface quality (Items 16–18).[47] Each item of the scale has seven response options ranging from "strongly agree" to "strongly disagree." Scores represent the mean response to the items in each subscale, ranging from 1 (good usability) to 7 (poor usability). The PSSUQ has been observed to be highly reliable and valid.[47,51]

RESULTS

Our evaluation indicated that, with the exception of Tasks 1 and 8 (identifying and intervening for urinary catheter and pressure ulcer risks, respectively), participants completed all tasks faster and with greater accuracy (no errors) using the dashboard than when completed with the conventional EHR system (Figures 2 and 3). Across all seven participants, the dashboard received a mean SUS score of 87.5 (SD, 9.6) and an overall PSSUQ score of 1.7 (SD, 0.5). Component scores of the PSSUQ included a system usability score of 1.5 (SD, 0.4), information quality score of 1.8 (SD, 0.8), and an interface quality score of 1.8 (SD, 0.8), suggesting that the dashboard had good usability.

The SUS score improved 4.5 points in comparison to the prototype dashboard, suggesting that changes made during the iterative development of the EHR functional dashboard were beneficial.[35] In both evaluations, participants had little difficulty operating the system. Specifically, participant ratings of SUS Statements 4 and 10 were generally very positive, suggesting good perceived learnability.[37] One participant noted that "The system was mostly self-explanatory, hence easy to use and learn." The overall PSSUQ and individual component scores, although not collected as part of the prototype evaluation, also suggested that the dashboard was intuitive to use. Several participants noted the "visual aspect of the system provided information at a glance for multiple patients." One participant

Table 3. Evaluation Tasks

1. Find a patient with a urinary catheter.
a. RN—Change nursing documentation for a urine catheter indicating it was discontinued an hour ago.
b. MD—Write an order to discontinue the urine catheter.
2. Find a patient at risk of delirium.
a. RN—Identify medications ordered that may accentuate delirium risk (BEERs criteria[a]).
b. MD—Write an order to discontinue a medication that may accentuate delirium risk (BEERs criteria).
3. Find a patient with unacceptable pain.
a. RN/MD—Identify the trend reported by the patient related to pain intensity.
4. Find a new patient with a urine catheter for more than 2 d.
a. RN/MD—Identify the insertion date, insertion unit, and type/location of urine catheter.
5. Find a patient that has a low Barthel Index (<50).
a. RN/MD—Identify if a physical therapy consult was sent.
b. RN/MD—Identify if the patient's functional status is improving.
6. Find a patient with a longer-than-expected length of stay.
a. RN/MD—Write a referral to social services for transfer to a long-term-care facility.
7. Identify a patient at risk of falling.
a. RN—Identify the risk factor contributing to that fall risk and document an intervention.
b. MD—Identify the risk factor contributing to that fall risk and write an order to progress their activity level and change the daily weight to avoid waking the patient during the night.
8. Find a patient at risk of developing a pressure ulcer.
a. RN/MD—Identify if nutrition is a contributing factor.
b. MD—Order albumin.

[a]The BEERs criteria identify medications whose risks outweigh their benefits and that should be avoided or used with caution in adults 65 years or older.[46]

volunteered that they are color blind, and the color display was still easily interpretable.

Despite generally positive results, several opportunities to improve the dashboard were identified. Most consistent recommendations from participants revolved around inclusion of additional quality indicators and patient warning "flags." For example, one participant recommended including bariatric status, whereas another recommended presence or absence of bed alarms be added. Unique patient characteristics such as a patient having a different primary language or use of a service dog were also suggested for inclusion. Other recommendations included making the dashboard touch screen capable and revising the layout to make all the information fit on one screen.

DISCUSSION AND CONCLUSIONS

Our findings on reduced task completion times and error rates suggest that the HIT dashboard could be a promising tool for improving the speed and accuracy of clinician decisions in the complex patient care environment. Observed improvements in participant performance are likely the result of keeping displays simple and avoiding visual "clutter" common to conventional EHR displays.[40,41] Several recent reviews of the scientific literature have suggested that cluttered displays result in substantial performance decrements including degraded monitoring and change detection, delayed visual search times, increased memory loading, and negative effects on situational awareness.[40,41] Faster, more accurate decisions while using the HIT dashboard may support the reduction of preventable medical errors and associated adverse events.

A multifaceted implementation plan has been used to promote use of the dashboard on 11 inpatient units at the medical center[52] with pilot use planned to occur for several months. Knowledge about use is being promoted through demonstration at meetings with individuals or teams in the clinical areas. Tip sheets provide guidance for each displayed indicator to promote early interprofessional planning. Local change agents on each unit are responsible to use the dashboard during interprofessional daily huddles. Integration of dashboard use in practice is being promoted by updating practice reminders, actionable feedback of quality improvement data, and reporting to senior leaders. The functionality of the EHR dashboard continues to evolve, leading to ongoing updates within the system and training of clinician users. Installation of more flat-screen monitors to improve convenient access for interprofessional care teams is a component of this implementation. Rollout to other patient populations is under development, with identification of key quality indicators for population-specific dashboards (eg, behavior health or critical care). Evaluation will involve using statistical process control charts to determine if significant improvements in associated quality outcomes displayed as quality indicators within the dashboard are achieved.

In the meantime, some early improvements have already been established. Among the anticipated quality improvements was accurate documentation of restraint use. Prior to dashboard implementation, patients transferred across inpatient units (eg, from ICU to general care unit) whose restraints were removed during the transfer were occasionally not documented as having restraint use discontinued. Identification of those patients with continued active restraints from using the dashboard during rounding led nurses to correct the patient record and convince the restraint committee to implement additional targeted quality improvement activities. Rounding teams are also finding similar improvements in care coordination and documentation for other displayed indicators (eg, urinary catheters). One unanticipated benefit was clear identification of vulnerable patients by easily identifying numerous indicators as "red" or at risk. Elderly patients waiting for discharge to a skilled facility, for example, were often not

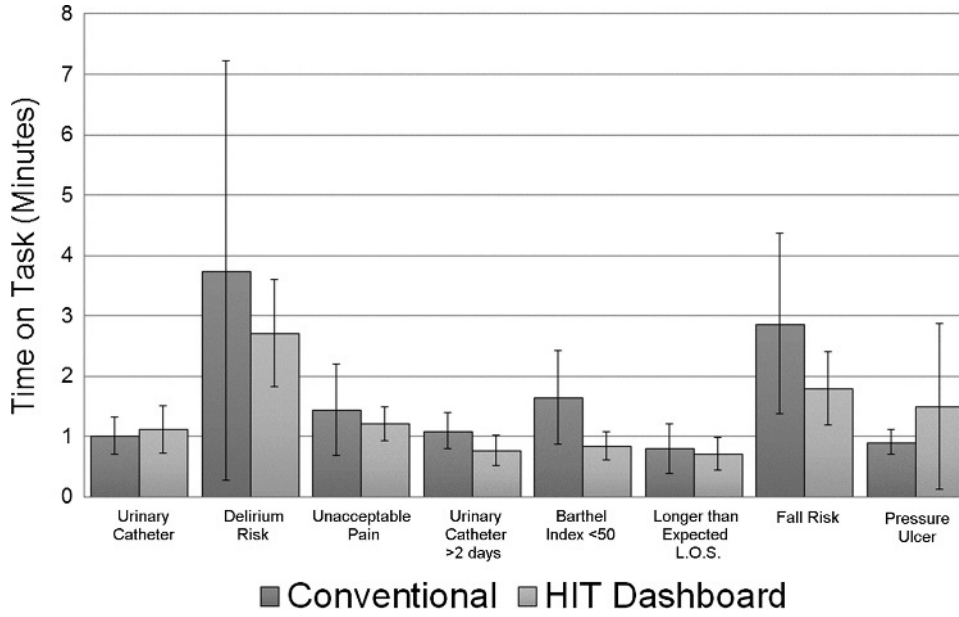

FIGURE 2. Time on task (in minutes) for the conventional EHR and dashboard (error bars represent SD). See Table 3 for further description of tasks. Note that observed differences were not evaluated for statistical significance.

recognized as being at high risk of contracting hospital-acquired conditions. These patients' needs are now considered when staffing assignments are made, to keep the acute level nursing coverage. Reporting use of the dashboard is now occurring within the quality program across disciplines in the organization. Additional postpilot evaluation will indicate if the dashboard and implementation strategies were effective.

There are several limitations to this work. First, the conventional EHR interface used as a reference comparison during evaluation of the dashboard was not customizable to each participant. The EHR has many options for personalizing information display. To provide a consistent platform across all participants, personalized EHR interfaces were not included, and participants may have been slowed by slight differences from their personal EHR display. In addition, participants were given only 10 minutes to train with the dashboard system and ask any questions immediately prior to completing the task-based evaluation. Although participants received this training, their performance may have been affected by their novice status.

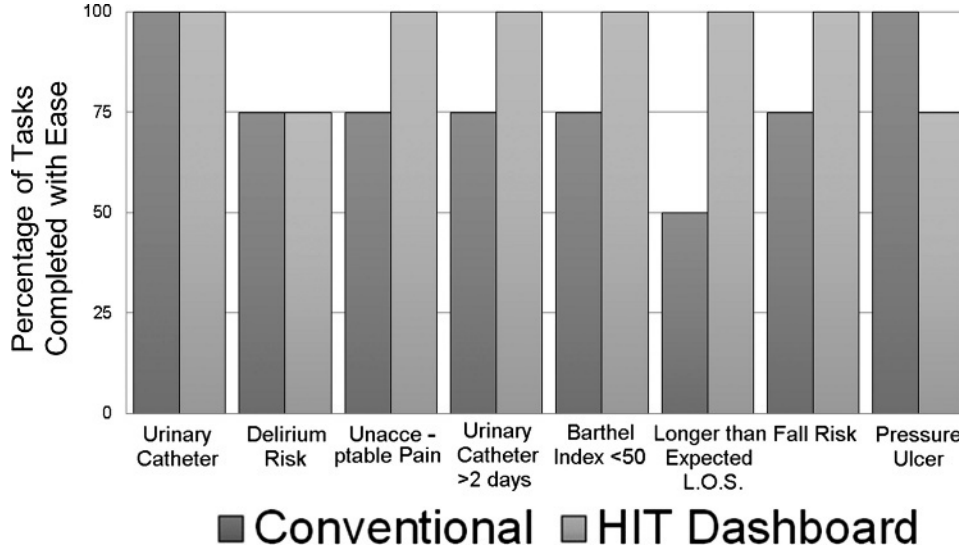

FIGURE 3. Percentage of tasks completed without error. See Table 3 for further description of tasks. Note that observed differences were not evaluated for statistical significance.

While participants noted that the dashboard was much easier to use to identify information quickly in comparison to the EHR during evaluations, tasks that required changing documentation or placing orders for activities (eg, Tasks 1 and 8) often took longer or led to more errors when using the dashboard because of limited functionality linking with ordering. Further steps to better integrate the dashboard within the EHR are necessary.

Finally, the scope of this study was small, limiting the generalizability of the results. Moreover, it should be noted that the usability evaluations were based on self-report, which is subjective to bias. The inability to blind participants to the outcome measure is a drawback that further limits generalizability. Regardless, this study represents one of the first attempts to design and analyze the effects of an EHR-integrated quality dashboard, providing an example for many institutions to apply a similar structure and design principles.

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