A human factors approach to improving electronic performance measurement of venous thromboembolism prophylaxis

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Abstract

Objective: In 2011, our institution developed a venous thromboembolism (VTE) prophylaxis order set to monitor prophylaxis management through physician-generated risk assessment orders. Prophylaxis rates obtained using the risk assessment orders were falsely low compared with chart review. Our goal was to redesign the order set to increase the percentage of VTE risk assessments ordered, both to improve care and to better reflect performance.

Design: Quality Improvement Project.

Setting: Veterans Health Administration.

Participants: Patients admitted to acute care and intensive care medical units.

Interventions: Process analysis was used to identify systems failures limiting use of the original order set. The order set was redesigned using a human factors approach.

Main Outcome Measure: VTE risk assessment orders.

Results: The order set was redesigned to reduce complexity and improve integration into provider workflow. The rate of risk assessment orders placed within 24 h increased from 48.6 to 80.4% (P<0.001). There was no difference in the actual use of prophylaxis. However, for patients on prophylaxis, the rates of having a documented ‘moderate’ or ‘high’ risk assessment within 24 h increased from 66.7 to 95.7% (P<0.001).

Conclusions: Using human factor principles to redesign an order set led to a significant increase in the percentage of patients with a risk assessment order placed within 24 h of admission. Although the risk assessments using the redesigned order set better reflected physician performance, it remained an imperfect measure for VTE prophylaxis. New technology used to measure human performance must be evaluated following implementation to assess accuracy.

Key words: performance measurement, venous thromboembolism prophylaxis, quality improvement
Introduction

Venous thromboembolism (VTE) prophylaxis is recommended for nonsurgical patients at increased risk for developing VTE during hospitalization [1]. In 2009, The Joint Commission included VTE prophylaxis performance measures as part of the core measures of hospital quality [2]. Today, individual hospital performance data for VTE prophylaxis rates are publicly available on Hospital Compare [3]. Despite the establishment of VTE prophylaxis as a publicly reported performance measure, prophylaxis in hospitalized patients remains underused. In a multinational study, only 40% of at-risk medicine patients received guideline-recommended prophylaxis [4]. Likewise, a recent multicenter cohort study reported that 30% of medical patients received prophylaxis on admission [5]. Prior studies have shown that embedding clinical decision support tools in the electronic medical record can increase adherence to national guidelines for individualized VTE risk assessments and VTE prophylaxis [6–9].

In 2011, our institution created a VTE prophylaxis electronic order set with the dual purpose of providing guideline-based decision support and permitting internal monitoring of VTE prophylaxis management. The order set was designed to generate a VTE risk assessment and either an order for guideline-supported prophylaxis or an order with documentation of a contraindication to prophylaxis. All medical patients were expected to have a risk assessment regardless of whether or not they met criteria for prophylaxis. The VTE risk assessment order was used as a process measure for provider VTE prophylaxis management, as tracking the number of risk assessment orders simplified the query to a single item rather than querying the system for all types of prophylaxis and potential contraindications. However, VTE prophylaxis management rates obtained using the VTE risk assessment orders were much lower than rates of appropriate VTE prophylaxis management obtained from chart review.

The accuracy of performance measures obtained from the electronic medical record is dependent on the methods of how data are recorded and queried [10, 11]. The limitations of electronically collected data can be significant and have led organizations, such as the National Healthcare Safety Network, to require that electronically collected data be validated against manually collected data [12, 13]. Due to concerns from both hospital administrators and physicians regarding inaccuracies in internal reporting of VTE prophylaxis, we sought to redesign the order set to meet the needs of both administrators and physicians. The aims of our project were to explore the systems issues that prevented completion of the original order set and to redesign the order set using a human factors approach. Our goal was to increase the percentage of medicine patients with a VTE risk assessment ordered within 24 h of admission to better reflect hospital performance.

Methods

Process analysis

The original VTE prophylaxis order set from 2011 was intended for use on all patients admitted to internal medicine (including subspecialties and intensive care) at the time of admission. The order set included orders for VTE prophylaxis (pharmacologic or mechanical) as well as for a VTE risk assessment (low, moderate or high). For patients with contraindications to pharmacologic prophylaxis, the ordering provider was asked to order sequential compression devices (SCDs) or to order a documented contraindication to SCDs in addition to ordering a documented contraindication to pharmacologic prophylaxis.

The original order set was examined using process analysis. Each menu and submenu of the order set was mapped (Fig. 1). The original order set was evaluated using a human factors approach to identify failure modes through discussions with medicine residents and attending hospitalist providers. Residents and hospitalists admit the majority of patients to our facility and are responsible for VTE prophylaxis decisions. Inpatient general medicine ward teams were approached and asked to discuss their experience using the VTE order set, including the circumstances under which they use the order set and problems they encountered in completing the order set.

Order set update and implementation

Using the information obtained during process analysis, a team was formed to update the VTE prophylaxis order set. The team consisted of two internal medicine physicians, a Clinical Pharmacy Specialist and an information technology (IT) specialist. The content of the original VTE order set was updated according to the 2012 Antithrombotic Therapy and Prevention of Thrombosis Guidelines and the Preventing Hospital-Acquired Venous Thromboembolism guide from the Agency on Healthcare Research and Quality [1, 14]. A new order set was drafted with an emphasis on streamlining menus and reducing information density [15]. Preliminary order set outlines were generated by the physicians on the team and edited with input from the Clinical Pharmacy Specialist. The final draft was submitted to the IT specialist for creation and placed in a test menu in the electronic medical record. The final order set was implemented on June 2014 (Fig. 2).

Data abstraction and coding

To assess for changes in risk assessment and prophylaxis ordering, charts from 1 week of medicine admissions before (March 2014) and after (September 2014) the implementation of the new order set were reviewed. Admissions were included if patients were admitted to one of the seven medicine units, including the medical intensive care unit and the coronary care unit. All admissions to non-medicine units were excluded. At the time of our study, our institution monitored risk assessment orders for all patients regardless of length of stay. Thus, all observation patients, patients admitted for <48 h, were included. Two study authors reviewed all charts to determine presence and timing of risk assessment orders and prophylaxis orders. Charts were also reviewed to determine whether patients were on full anticoagulation or had a documented contraindication to VTE prophylaxis. Data were collected using an abstraction tool.

Statistical analysis

Based on a preliminary data obtained during the process analysis phase, we believed that a redesigned order set could increase the number of risk assessment orders from 40% at baseline to at least 60%. A sample size of 97 for each sample was required for a power of 0.80 and significance level of 0.05. Risk assessment orders, prophylaxis orders, full anticoagulation orders and presence of a contraindication for each patient were summarized using descriptive statistics. Categorical data were analyzed using the Pearson’s chi-squared test. All analyses were performed using Stata 13.1 (StataCorp).

Human subjects

This study was approved by the Institutional Review Board at Baylor College of Medicine and the VA Research and Development Committee at the Michael E. DeBakey VA Medical Center.
Results

We identified three key failure modes that impacted the usability of the original order set through detailed process analysis (Fig. 1). First, the original order set was overly complex and created excess work for the end user. Completion of the original VTE order set required up to 12 mouse-clicks through 9 different screens. In contrast, prophylaxis-dosed subcutaneous heparin could be ordered through an alternative path using a different order set with 4 mouse-clicks and 4 screens, which bypassed the risk assessment order. Second, the order set was not linked to all admission order sets. For patients admitted with delayed orders, the order set did not appear automatically when providers began to enter admission orders; the provider had to make a conscious choice to find the VTE order set in a list of available additional options. Thus, providers might either overlook or deliberately bypass the VTE order set. Finally, for low risk patients and for patients with contraindications to prophylaxis, the original VTE order set could be completed without generating a risk assessment order. For example, in the baseline sample, providers used the order set to order mechanical prophylaxis for 33 patients, but only generated risk assessment orders for 19 of those patients.

Based on physician input, the redesigned VTE order set focused on improving usability and incorporating the order set into physician workflow. We were able to streamline the order set to two screens, while maintaining the decision support from the original order set (Figs 2 and 3). The risk assessment was placed on the first screen that required completion before providers could move to the next screen, thus employing a forcing function [16]. The second screen allowed providers to choose pharmacologic prophylaxis or mechanical prophylaxis or a contraindication to pharmacologic prophylaxis for moderate- and high-risk patients. Formatting of the educational content regarding risk for VTE and appropriate options for prophylaxis was improved by reducing information density through the use of columns and appropriate headings [15]. With the reduced complexity of the new order set, providers were able to generate both the prophylaxis order and risk assessment order in five or fewer mouse-clicks for all patients. To improve workflow integration, the order set was attached to all types of admission orders used by providers. This ensured that the VTE order set would automatically open with all admission orders.

There were 181 admissions in our baseline sample with 158 following the introduction of the new order set. The majority of admissions in each sample were to general medicine services, which remained stable between the two time periods (76% baseline, 78% follow-up sample). The remaining admissions were to medicine subspecialty services, the medical intensive care unit and the coronary care unit.

Following the introduction of the new order set, the percentage of patients with a risk assessment ordered within 24 h of admission...
increased from 48.6 to 80.4% \((P < 0.001, \text{Table 1})\). With the original order set, two patients received a ‘low’ risk assessment and both received mechanical prophylaxis. With the new order set, five patients received a risk assessment of ‘low’ and none of these patients received mechanical or pharmacologic prophylaxis. The percentage of patients actually receiving VTE prophylaxis based on chart review did not change after the introduction of the new order set (68.0–75.3%, \(P = 0.14\)). However, the percentage of patients receiving VTE prophylaxis and a ‘moderate’ or ‘high’ risk assessment order significantly increased \((P < 0.001)\). With the redesigned order set, 95.7% of patients who had an order for VTE prophylaxis also had a ‘moderate’ or ‘high’ risk assessment order placed within 24 h of admission. For those admissions without a risk assessment, the majority had orders for full anticoagulation, an order for VTE prophylaxis, or a contraindication to prophylaxis in the admission history and physical (Table 2).

**Discussion**

We redesigned the VTE prophylaxis order set using human factors principles and were able to significantly increase the number of patients with a VTE risk assessment order within 24 h of admission. We found several failure modes in the original order set that impacted the generation of a risk assessment order and limited the hospital’s ability to monitor VTE prophylaxis. There was no difference in the actual use of VTE prophylaxis before and after the implementation of the new order set, based on chart review. The significant increase in the percentage of patients with both VTE prophylaxis and a ‘moderate’ or ‘high’ risk assessment suggests that providers frequently were bypassing the original order set or completing the original order set without ordering a VTE risk assessment. The risk assessment order remained an imperfect internal monitor for appropriate VTE prophylaxis management, with almost 20% of patients lacking a risk assessment order, though many of these patients received appropriate treatment decisions regarding VTE prophylaxis.

To be successful, clinical decision support tools must be designed with the needs of the end user in mind. Electronic tools must be fast, simple, anticipate users’ needs and fit into users’ workflow \([15, 17]\). The use of basic human factors techniques, such as improving usability of electronic tools through reducing mouse clicks and changing how content is viewed on screen, has been shown to positively impact provider performance \([18]\). Our findings further demonstrate how simplification of an electronic order set and integration of the order set into provider workflow can change ordering habits of providers. Despite the significant improvements in the number of patients with a VTE risk assessment order with the new order set, the risk assessment remained an imperfect measure of provider VTE prophylaxis management. In our current system, there is no forcing function that requires providers to complete the VTE order set. Providers who believe that the order set does not pertain to their patient (e.g., a patient on full anticoagulation) are able to close the order set without ordering a risk assessment. The use of a force function that requires providers to complete the order set may be one method to further increase the number of risk assessments ordered.

Electronic medical records offer an important opportunity to facilitate internal monitoring of physician and hospital performance for quality improvement. Although the percentage of risk assessments ordered increased significantly and better reflected VTE prophylaxis
prescribing practices, 20% of patients still did not have a risk assessment within 24 h of admission. The majority of these patients without a risk assessment were appropriately managed for VTE prophylaxis. The limitations of gathering data electronically must be fully understood to prevent inaccurate conclusions regarding physician performance [10, 11, 19]. Performance measurement is a source of contention for many providers who feel that performance measures result in mandates of care that are clinically inappropriate and inconsistent with patient-centeredness [20, 21]. The use of electronic data that does not accurately reflect performance will only exacerbate these frustrations, unless the limitations of electronic data are understood and the methods by which data are obtained are transparent to stakeholders [22].

This is a single institution study and addresses a unique institution-specific question regarding the electronic medical record and internal performance monitoring. However, the methods that we used to evaluate and redesign the order set are generalizable to other institutions who utilize electronic medical records to monitor physician performance. Our project focused specifically on improving the number of risk assessments ordered, which was the internal process measure adopted at our institution to monitor physician performance. As a process measure, VTE risk assessments may not reflect appropriate

Figure 3 Order screens of redesigned order set.
prophylaxis use or the safety of prophylaxis choice. We acknowledge this as a limitation of our study; however, other health care systems have used documentation of VTE risk assessments to monitor VTE prophylaxis management and guide local quality improvement efforts [23].

In the bigger picture, any introduction of new technology can have a lasting impact on how providers work. Although technology can be designed with human factors principles in mind, it may be difficult for both human factors engineers and providers to fully anticipate how new technology will be incorporated into clinical practice [24].

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Proportion of risk assessment and prophylaxis orders before and after implementation of redesigned order set</th>
</tr>
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<tbody>
<tr>
<td>Before implementation</td>
<td>After implementation</td>
</tr>
<tr>
<td>(n = 181)</td>
<td>(n = 158)</td>
</tr>
<tr>
<td>Risk assessment ordered within 24 h&lt;sup&gt;a&lt;/sup&gt;</td>
<td>88</td>
</tr>
<tr>
<td>VTE prophylaxis ordered within 24 h&lt;sup&gt;b&lt;/sup&gt;</td>
<td>123</td>
</tr>
<tr>
<td>VTE prophylaxis or full anticoagulation ordered within 24 h&lt;sup&gt;b&lt;/sup&gt;</td>
<td>147</td>
</tr>
<tr>
<td>Moderate or high-risk assessment and VTE prophylaxis ordered within 24 h</td>
<td>82</td>
</tr>
</tbody>
</table>

<sup>VTE</sup>, venous thromboembolism.<br>
<sup>a</sup>Denominator is total number of admissions.<br>
<sup>b</sup>Denominator is total number of admissions with VTE prophylaxis ordered within 24 h.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Orders and clinical documentation for patients without a risk assessment</th>
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<tbody>
<tr>
<td>Before implementation</td>
<td>After implementation</td>
</tr>
<tr>
<td>(n = 93)</td>
<td>(n = 31)</td>
</tr>
<tr>
<td>Full anticoagulation</td>
<td>22</td>
</tr>
<tr>
<td>Pharmacologic or mechanical prophylaxis without risk assessment within 24 h</td>
<td>37</td>
</tr>
<tr>
<td>Listed contraindication in admission history and physical</td>
<td>8</td>
</tr>
<tr>
<td>Admitted for a procedure</td>
<td>12</td>
</tr>
<tr>
<td>No prophylaxis, anticoagulation or listed contraindication within 24 h</td>
<td>14</td>
</tr>
</tbody>
</table>

Figure 3 Continued
our study illustrates, the impact of something as small as an order set cannot be fully understood until end users have an opportunity to use the technology in a real work environment.

Technology holds significant promise to make health care safer and more efficient. The introduction of new technology does not replace human work but rather changes how providers work within their system [24]. New technological changes, even small changes such as order sets, must be evaluated following implementation to understand how technology is used in practice. This evaluation is particularly important when new technology is tied to the monitoring of physician performance. With the number of performance measures growing and the continued efforts to develop technology that will measure performance, new technology must be designed and evaluated using a human factors approach to maximize usability and accuracy.

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