Design, Development and Implementation of a Computer-Based Anticoagulation Order Set with Embedded Decision Support

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Abstract

Given the high risk of anticoagulation medications and the recent Joint Commission requirements, hospitals are mandated to implement strategies to optimize ordering and management of anticoagulants. We describe the design, development, and implementation of a novel computer-based anticoagulation order set with embedded decision-support for adult inpatients. The order set is fully-integrated into our enterprise-wide computerized physician order entry system.

A multidisciplinary Project Management Team was convened in January 2007 to review the current literature, recommend dosing guidelines, define design specifications, develop workflow integration, and perform beta testing of the order set. In November 2007, the system was implemented at Bellevue Hospital, a 912-bed acute care facility and has shown high physician adoption rate.

We also discuss various informatics, clinical, workflow, and organizational challenges during the project and our approach to resolving them. Research to evaluate the impact of the system on clinical processes and patient outcomes is underway.

Introduction

Anticoagulation medications such as heparin and warfarin are commonly associated with adverse drug events in the inpatient setting because of their complex dosing, adjustment, and monitoring requirements (1). Reducing the likelihood of patient harm associated with anticoagulation is a Joint Commission 2008 national patient safety goal (2). Therefore, hospitals are now mandated to develop strategies to improve the dosing and monitoring of these high risk drugs so as to reduce the frequency of bleeding and thromboembolic complications.

Physician ordering practices for anticoagulation can be improved with the use of standardized nomograms for heparin and warfarin administration (3, 4). Information technology such as computerized physician order entry (CPOE) has been employed to facilitate the use of nomograms and improve the quality of anticoagulation administration (5). However, computerized tools to modify physician ordering practice are often plagued by low utilization (6).

We describe the design, development and implementation of a novel computer-based anticoagulation order set with embedded decision-support for adult inpatients that is fully integrated into our enterprise-wide CPOE. We also discuss various informatics, clinical, workflow, and organizational considerations in the deployment of the system. Our initial implementation at one acute-care hospital has demonstrated high physician adoption rate and satisfaction.

Methods and Setting

New York City’s Health and Hospital Corporation (HHC) is a public benefit corporation governing 7 regional networks that include 11 acute care hospitals, 80 clinics, and six diagnostic and treatment facilities. HHC serves 1.3 million patients totaling 222,200 discharges and 4.9 million outpatient visits annually. HHC has widely implemented and used an electronic health record (EHR) for over ten years at various hospitals including a CPOE system for ordering medications.

Recognizing the need to address the prevention and treatment of thromboembolic disease, a corporate-wide multidisciplinary “DVT / PE Committee” was convened in September 2005. The first phase of the project included designing and implementing an electronic risk assessment tool and prophylaxis order sets for the prevention of thromboembolic disease. Spurred by the requirement to address the safety of anticoagulation medications, the second phase of the project was launched to develop and implement electronic anticoagulation order sets for therapy integrated within the CPOE system. The objectives of this system included:

(a) Improving adherence to evidence-based anticoagulation guidelines and reducing variation in dosing protocols across HHC,
(b) Improving safety by providing point-of-care decision support during the ordering process, and
(c) Improving communication between physicians, pharmacists, and nurses for anticoagulation management.
To kick-off the anticoagulation order set project, a multidisciplinary Project Management Team (PMT) was created in June 2006, including physicians, pharmacists, nurses, laboratory and information technology personnel, and project managers from various networks. The PMT incorporated three subgroups:

1. Functional specifications subgroup – reviewed current literature, recommended standard anticoagulation dosing guidelines, and defined design specifications for the system.
2. Workflow subgroup – designed the program to conform to usual clinical workflow patterns.
3. Beta testing subgroup – tested the system after the build was complete.

The PMT and various subgroups met regularly and delivered the initial design and build in March 2007. Subsequently, 30 clinicians, including physicians and pharmacists as well as IT representatives performed beta testing at various hospitals. Beta testers requested 52 changes which were grouped into the following categories: decision support - 29, workflow - 10, screen design - 8, policy - 2, and miscellaneous - 3. The functional specifications subgroup used many of these suggestions to develop revisions for the final design of the system. Some suggestions were designated for customization at the individual hospital level to accommodate local practices. For example, it was recommended that each individual facility develop a formal process to ensure that aPTT reference ranges in the system accurately reflect the local laboratory references ranges which can vary according to the specific reagents and coagulometer in use.

The proposed anticoagulation order set was presented to the HHC Medical Directors’ Council for review and approval. A pilot site was chosen to test the system based on strong physician and IT support. The pilot was comprised of a design phase which included building and testing of the IT system, a training phase, and finally implementation. In November 2007, the system was implemented at Bellevue Hospital, a 912-bed acute care facility in Manhattan. During the first week, limited adoption by physicians was observed despite end-user education and communication of the need for compliance to department heads. The system was then enhanced rendering its use mandatory with a resultant improvement in compliance and clinician acceptance.

Quality measures were developed by the Project Management Team to assess process and clinical outcomes for this program. A schedule was developed to implement use of this system across all of the remaining HHC hospital facilities.

The Computer-based Anticoagulation System

The system incorporates ordering and management guidelines for heparin (initial and adjustment dosing), warfarin, enoxaparin (Lovenox), and dalteparin (Fragmin). The key features of the system are outlined below (Figure 1):

(a) Dosing recommendations, based on weight and/or laboratory results (such as aPTT or INR), derived from evidence-based guidelines (7-9),
(b) Automated ordering of corollary lab orders such as CBC, aPTT and platelet count with medication ordering,
(c) Trend report, built in the order set, summarizing historic anticoagulation medication and pertinent lab ordering from the last 10 calendar days available from the order entry screen,
(d) Point-of-care decision support including:
   - No weight alert – preventing physicians from ordering medications without documented weight
   - Weight consideration alert – if weight was documented more than 72 hours ago
   - Platelet warning alert during heparin ordering – if platelet counts are less than 100,000/mcl or if there is a decrease in platelet counts greater than 50% over the last 10 calendar days.
   - Baseline lab warning – if appropriate baseline labs such as aPTT, INR, or platelets have not been completed prior to ordering anticoagulants.

Heparin: Initial weight-based heparin dosing, including both bolus and IV drip rate, was divided into high, intermediate, and low dose pathways. The high dose pathway was indicated for patients with DVT and pulmonary embolism (PE); the intermediate for patients with cardiovascular or vascular indications including atrial fibrillation. The low dose pathway was designated for patients who received thrombolytic therapy for myocardial infarction. A fourth pathway was designed for patients with acute stroke or recent surgery, for whom a heparin bolus was not indicated.

Included on the intravenous heparin face sheet is a warfarin initiation nomogram selection which serves
Figure 1: Electronic anticoagulation order set: Heparin order entry screen

as a reminder to the provider to consider early oral anticoagulation therapy. Calculations of heparin bolus and maintenance doses are performed automatically once the selection of an order set is made as long as a patient weight has been entered within 72 hours.

The adjustment of heparin dosing based on aPTT values and weight was divided into high and low dose adjustment pathways. The high dose adjustment pathway was designated for patients with DVT or PE and the low dose pathway for all others. Based on indication, weight, and aPTT value, the pathway makes a recommendation to the ordering physician for IV drip rate changes and IV bolus if indicated.

The system automatically converts the heparin dose from units into an infusion rate in milliliters / hour using a standardized concentration of heparin. Once a heparin order is initiated or changed, the pathway automatically orders aPTT to be drawn 6 hours later.

**Warfarin:** The warfarin order set, based on the 5-mg nomogram (7, 8), was used only for the initiation of warfarin, and not for maintenance therapy. All patients were started on 5 mg of warfarin as the initiation dose for both days 1 and 2, followed by protocol recommendations on days 3-6 based on INR result.

**Dalteparin:** The dalteparin order set included two dosing options, first for unstable angina, and the second for all other diagnoses. The second pathway was further divided into once or twice daily dosing. The maximum dose of dalteparin that could be given over the course of 1 day, irrespective of weight, is 20,000 units. Dosing options greater than 20,000 units per day are not allowed by the system.

**Enoxaparin:** The enoxaparin order set included three weight-based dosing options: once every 12 hours, once a day, and a renal failure order set. For each dosing option, there is a minimum (57 kg in males, 45 kg in females) and maximum weight set (150 kg) to avoid excessively low or high dosages.

**Discussion**

It has been suggested that CPOE with decision support improves patient safety and reduces medication errors (10). CPOE order sets and collections of pre-formed quick orders streamline the ordering process, improve CPOE efficiency, and improve adherence to proper dosing guidelines (10). In this section, we describe various challenges and resulting design changes during development and implementation of electronic anticoagulation order sets.

**Informatics considerations:** Effectively translating evidence-based guidelines into clinical practice by
means of order sets and decision-support remains a significant challenge for the developers of information systems. We did not attempt to convert anticoagulation guidelines into a “computer-readable” document as in the document-centric model proposed by Shiffman et al (11). Instead we converted the guidelines into discrete actionable medication orders as discussed by Waitman and Miller (12).

Because of the multitude of guidelines for different clinical conditions, we decided to use an intensity-based heparin dosing protocol (high, intermediate, and low-dose) developed in accordance with evidence-based guidelines for common diagnostic categories.

Since clinical knowledge and therapeutic guidelines advance rapidly, it is critical for the order sets to be reviewed and updated periodically. We have mandated the PMT project manager to review the clinical evidence at least once a year and update the order sets accordingly.

Even when the quality of evidence-based order sets is excellent, most CPOE order sets suffer from low utilization because their use is often optional. During the initial week of the implementation at Bellevue Hospital, we observed that less than 10% of all anticoagulation treatment orders were placed using the order set despite end-user education, the presence of project team consultants on the wards to interact with housestaff, and communication regarding the system to department heads. We designed a novel approach to address this challenge by building constraints in the CPOE system which mandate that anticoagulation medications for treatment (as opposed to prophylaxis) for all adult inpatients could be ordered only using the order set. This immediately resulted in >99% of the orders being placed through the order set pathway.

As discussed by Bates et al (13), optimal decision support systems should also have the capability to anticipate the “latent needs” of clinicians. By automatically placing corollary orders for labs such as CBC, aPTT, and INR, our system anticipates the clinicians’ needs and eliminates the possibility of omission of relevant laboratory ordering. The trend report, summarizing pertinent lab results and medication orders for the last 10 days, available from the order entry screen also improves physician efficiency by providing multiple additional information points at the time of ordering without the necessity of an additional search.

Clinical and workflow considerations: For weight-based dosing to work in the clinical setting, it is mandatory that the clinical users are already recording the patient’s weight in the EHR in kilograms. Our EHR also allows users to enter an ‘estimated’ weight for dosing calculations if an actual weight cannot be obtained. Recognizing that even adult patients can have clinically significant fluctuations in weight during hospitalization, such as after changes in fluid status, we added an alert if the weight documentation was more than 72 hours old.

We decided that the system would only ‘suggest’ a dose based on weight, recent laboratory results (e.g. aPTT or INR), and the pathway selected (e.g. high, intermediate, or low dose for heparin). The ordering physician still must order the actual dose because of several considerations. First, the protocol does not take into account all clinical variables (like recent bleeding). Second, the calculated dose e.g. “4503” units of heparin for bolus may require rounding to clinically relevant units. Third, in the case of dalteparin, doses recommended by the weight-based protocol of 100u/kg, may result in a dose that is difficult to administer based on the size of pre-filled syringes commonly stocked in pharmacies. For example, the dose calculated for a 53.3 kg patient, is 5330 units. Pre-filled dalteparin syringes are only available in increments of 2,500 units. Therefore, to avoid the wasting 85% of a dalteparin syringe to administer the precise dose, the system recommends rounding to the nearest lower dose.

For each dosing option, there is a maximum weight (such as 150 kg for enoxaparin) or maximum allowable dose (such as 8000 units for the high-dose pathway for initial heparin therapy). This prevents excessively large doses in obese patients by providing an upper dosing limit.

For warfarin dosing, a 5-mg warfarin initiation was chosen because it is associated with a lower risk of bleeding compared to 10-mg protocols (14).

Organizational considerations: A multi-disciplinary project team enabled us to identify and address potential failure points early in the process. For example, active involvement of pharmacists facilitated discussions and system changes regarding appropriate ‘rounding’ of computer-suggested doses based on dispensing unit considerations. Laboratory personnel helped to identify a potential problem in that aPTT results above 100 are often reported as “>100” without provision of an exact number. Laboratories were asked to comply with guideline
recommendations to provide a more exact value for these results.

Limitations: As described in the previous section, the order set only ‘suggests’ a dose but the ordering physician enters the actual dose to allow clinical considerations and judgment to be factored into dosing determinations that cannot be included in a protocol-based dosing calculation. Our system is not able to perform automated calculations for the variance between the suggested and actual dose and alert the physician if there is excessive variance. The usual CPOE drug-dose alerts still apply.

Lessons Learned
While evidence-based guidelines are useful for initial development of order sets, a multi-facility, interdisciplinary team was crucial to resolve many practical issues that arose during design and implementation of a system for use in a large complex healthcare network. Our experience also highlights difficulties in conversion of paper-based guidelines into electronic order sets as evidence-based guidelines often have multiple branch points and ambiguities that are not easily amenable to computerization. Last, beta testing with direct feedback from end users was essential for revision of the system to enhance compatibility with clinical thought process and workflow patterns.

Conclusion
Our report has described the successful deployment of a computer-based anticoagulation order set in an enterprise-wide CPOE and various associated challenges and solutions. We are currently evaluating the impact of this order set on patient care processes and outcomes.

References