A Theory-based Evaluation of a Clinical Decision Support System to Predict New Onset of Delirium

Siru Liu, PhD[1], Adam Wright, PhD[1], Joseph J. Schlesinger, MD, FCCM[2], Thomas J. Reese, PharmD, PhD[1], Edward Qian, MD[3], Elise M Russo, MPH, PMP[1], Matthew W. Semler, MD[3], Brian J. Douthit, PhD, RN-BC[1,4], Allison B. McCoy, PhD[1]

[1]Department of Biomedical Informatics, Vanderbilt University Medical Center, Nashville, TN; [2]Department of Anesthesiology, Division of Critical Care Medicine, Vanderbilt University Medical Center, Nashville, TN; [3]Department of Medicine, Division of Allergy, Pulmonary, and Critical Care Medicine, Vanderbilt University Medical Center, Nashville, TN; [4]Tennessee Valley Healthcare System, U.S. Department of Veterans Affairs

Introduction

Delirium is an acute decline in cognitive function leading to confusion, which occurs in 29% to 65% of hospitalized older patients[1]. Patients with delirium experience a serious constellation of neuropsychiatric symptoms, resulting in higher mortality, in-hospital falls, and need for long-term care. Prevention is considered the most effective way to control delirium, and more than two-thirds of delirium cases are preventable[2]. Providing timely notification to clinicians of high-risk patients through clinical decision support (CDS) might have the potential to improve delirium prevention. In Stage I, we developed an explainable machine learning model to predict new onset delirium in hospitalized patients using electronic health record (EHR) data with an Area Under the Curve of 0.927 [0.924, 0.929]. In Stage II, we conducted a user-centered design process to design an explainable machine learning-based CDS tool. In Stage III, we focused on implementation and evaluation of a CDS tool to predict risk of new onset of ICU delirium.

Methods

The CDS tool was developed and implemented into the Epic EHR system at Vanderbilt University Medical Center (VUMC) in Nashville, TN. This study focused on the Medical (MICU) and Neurological Intensive Care Units (NICU), with a total of 69 beds.

The CDS tool is available to clinicians on the ICU care team (nurses, nurse practitioners [NPs], and attending physicians) through a column that users can add to existing patient lists within the EHR (Figure 1). The CDS tool was implemented using print groups and scoring systems within Epic without the need for external applications. The CDS tool is updated in real time as new data are generated. Prediction scores are automatically recorded hourly in a flowsheet for retrospective analysis. Scores are labeled red (>60%), yellow (25-60%), green (1-24%), and gray (0%) based on risk value. For patients in a coma, the score is followed by an asterisk. For delirious patients, the risk of new onset delirium is 0. In the hover message, modifiable and unmodifiable features contributing to that prediction are listed. In addition to the model explanation, the most recent Richmond Agitation-Sedation Scale (RASS) score, Confusion Assessment Method for the ICU (CAM-ICU) assessment, and the frequency of neuro check order are presented, based on the identified user needs in Stage II. When users click the score, the flowsheet is opened to review the historical assessments and record new values.

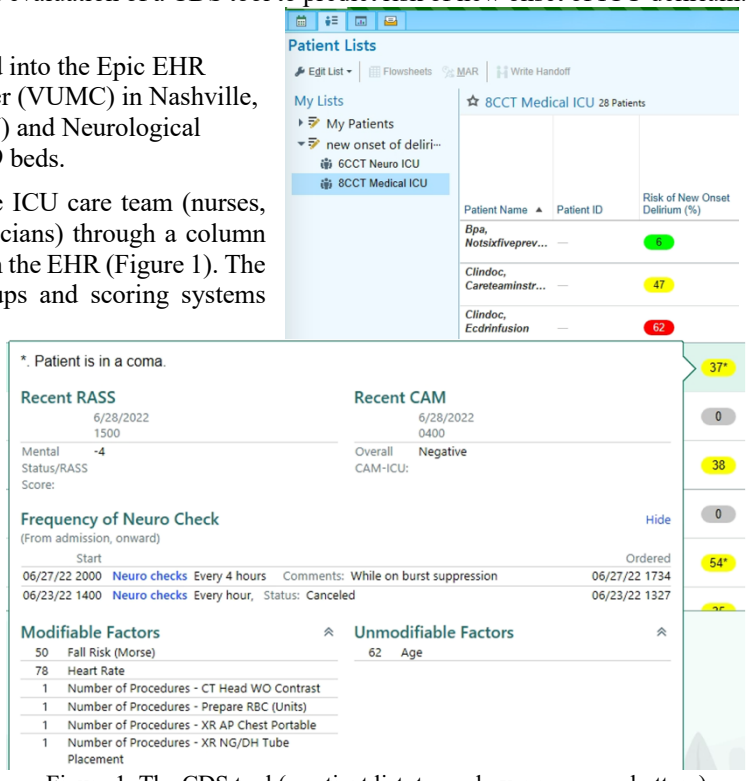

Figure 1. The CDS tool (a patient list: top; a hover message: bottom).

We performed semi-structured interviews with follow-up questionnaires to evaluate the CDS tool. The guide for semi-structured interviews was informed by a theoretical model – the Unified Theory of Acceptance and Use of Technology (UTAUT) model combined with motivational control (Figure 2). It was designed to guide CDS design and implementation[3]. The interview guide was pilot tested with an attending physician. The questionnaire included the

System Usability Scale (SUS)[4], the likelihood of recommending this CDS tool to others, and user satisfaction. Each item was measured on a five-point Likert scale. A system with a SUS score>80.3 was considered to have excellent usability[4]. Two moderators (SL and ER) led interviews and took field notes. We audio-recorded and transcribed all the interviews. All sensitive information related to participants was anonymized. We conducted a thematic analysis through NVivo 12 with an open coding scheme.

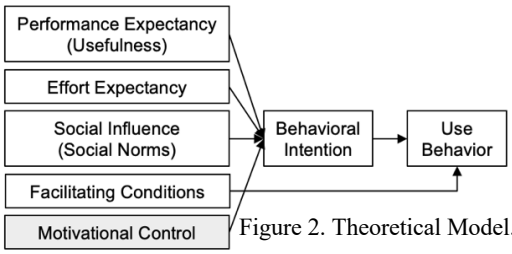

Figure 2. Theoretical Model.

Results

Eight users accessed this CDS tool for a total of 6543.27 s. We interviewed six of these clinicians. The average work experience was 9.1 years. The mean SUS score was 90.5. The likelihood of recommending this CDS tool to others and overall satisfaction on a 5-point Likert scale were both 3.6.

Performance Expectancy: Overall, participants showed positive attitudes. They indicated that the display of predicted scores on the patient list allowed them to have a comprehensive view of a group of patients. The CDS tool embedded in the EHR provides real-time predictions. They highlighted that an advantage of this tool was to "present the risk of delirium in a numerical format on a reasonable scale, which is easily interpretable." One participant emphasized its usefulness in certain situations, e.g., to provide a timely reference for clinicians who are less familiar with the patient's neurological condition. They mentioned that listing modifiable and nonmodifiable factors separately can increase actionability. Meanwhile, one clinician noted that some surgical procedures were unmodifiable factors. Participants indicated that this CDS tool might influence their decision-making process by allowing them to focus on delirium risk and take appropriate interventions for high-risk patients, e.g., avoiding some specific medications, ordering delirium precautions, increasing natural light, and increasing the family presence at the bedside. Regarding how to improve usefulness, nurses on the MICU unit indicated that the frequency of neuro check in their unit was Q4 by default, and that they would prefer to know family presence at the bedside. Some nurses noted a desire to show the risk of new onset delirium in both the flowsheet after each primary assessment and in the new management system for nurses (i.e., the Brain). Some clinicians were less certain about the continued use of the CDS tool because they were 1) familiar with the patient's situation (e.g., 1 nurse caring for 2 patients), and 2) unsure about actionable steps.

Effort Expectancy: Participants indicated that the CDS tool was easy to add to the patient list and easy to use. It required minimal effort without interrupting workflow. They also mentioned that the high frequency of using the patient list (>30 times/day) would make risk values for new onset delirium more noticeable. One attending physician suggested marking delirious patients as red to increase their attention. Another attending physician preferred to increase visualization by displaying outliers in different colors for modifiable and nonmodifiable factors.

Social Influence, Facilitating Conditions, and Motivational Control: Participants mentioned ICU culture as a facilitator for implementation and that more people would use this tool if it were added to their daily practice. Additional facilitating conditions included: introducing the tool and installation process in faculty meetings, automatic installation into the patient list using an opt-out strategy, and using a clickable pop-up window to install the CDS. One physician suggested adding a component to display the reliability of the model to increase their trust in the predicted values.

Discussion

Through this study, we implemented a CDS tool using functionality from an EHR vendor and theoretically evaluate clinician acceptance. The current CDS tool achieved excellent usability and good user satisfaction. However, these interviews also highlighted the importance of increasing clinician engagement, simplifying the CDS installation process, and providing actionable information. The CDS tool will be further tested in a randomized control trial at VUMC. Presenting explainable machine learning through patient lists is a low-cost and rapid implementation approach that can effectively integrate predictions into the clinical workflow.

Acknowledgements: The authors do not have conflicts of interest related to this study. This work was supported by NIH grant: R01AG062499-01.

References

1. Inouye SK, Westendorp RGJ, Saczynski JS. Delirium in elderly people. *Lancet*. 2014;383(9920):911-922.
2. Marcantonio ER, Flacker JM, Wright RJ, Resnick NM. Reducing delirium after hip fracture: a randomized trial. *J Am Geriatr Soc*. 2001;49(5):516-522.
3. Liu S, Reese TJ, Kawamoto K, Del Fiol G, Weir C. A theory-based meta-regression of factors influencing clinical decision support adoption and implementation. *J Am Med Informatics Assoc*.
4. Brooke J. SUS: A "Quick and Dirty" Usability Scale. In: *Usability Evaluation In Industry*. Vol 189. CRC Press; 1996:207-212.