Human-Centered Design of a Visual Analytics Dashboard for In-Hospital Clinical Deterioration in Children

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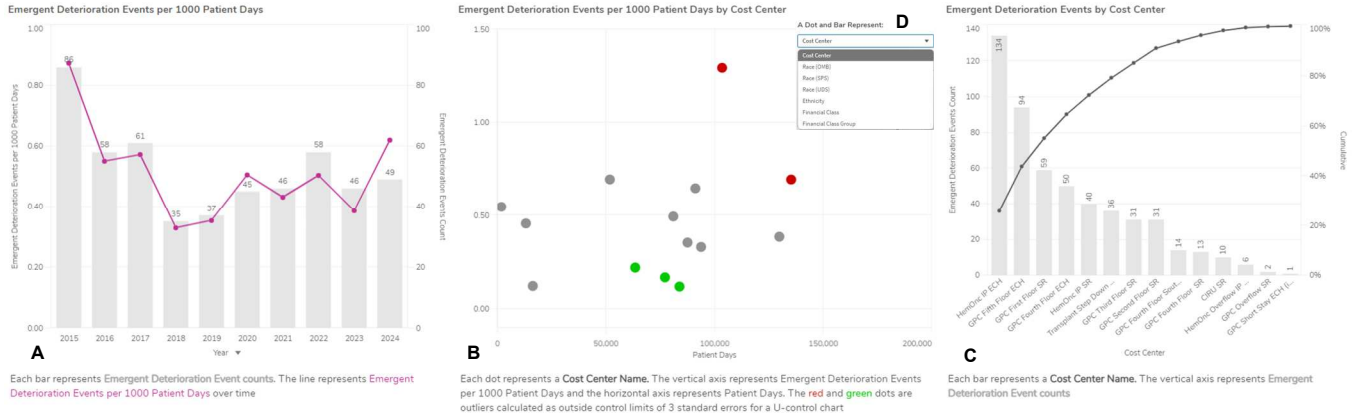[2] Emory University, Atlanta, GA, USA

Figure 1: Three visualizations for Emergent Deterioration Events to (A) track rates of deterioration over time, (B) identify inequities and outlier care areas, and (C) identify areas with high prevalence. The dropdown box (D) controls the 2nd and 3rd visuals to stratify by unit or demographics (race, ethnicity, or financial class) to identify outliers and primary contributors.

ABSTRACT

To monitor trends for late recognition of deterioration, developing a visual analytics dashboard helps address clinical deterioration rates in pediatric health systems. The dashboard enables ongoing trend analysis and detecting outliers in patient demographics or hospital units through control chart implementation using control limits set at 3 standard errors. The deterioration outcomes are defined by published evidence where EHR documentation can inform the cohort needing ICU interventions within a specific time.

Index terms: Human centered design, visual analytics dashboard, pediatric clinical deterioration, outlier detection, longitudinal trending, phenotype, UTAUT survey.

1 INTRODUCTION

Children with emergent deterioration while in the hospital, defined as transfer to the ICU and requiring ICU-level interventions within 1 hour of ICU transfer, are at significantly increased risk of mortality. Early recognition of deterioration leading to longer lead time between ICU transfer and requiring ICU-level interventions is associated with reduced mortality [1]. To assist a multidisciplinary team in mitigating these events, we leveraged human-centered design to create a visual analytics dashboard focused on clinical deterioration.

2 METHODS

We used a three-pronged approach to develop and assess our dashboard. Initial steps involved creating and refining SQL queries and data sets, leveraging EHR data to confirm the phenotype's integrity. We shaped the dashboard's design in Qlik, followed by a focused usability evaluation with key stakeholders to ensure its effectiveness.

2.1 Phenotype Validation

We developed queries for (1) deterioration defined intubation or vasoactive medications administered between 2 hours prior to and up to 12 hours after ICU transfer and (2) emergent deterioration defined as the same interventions in the first hour after ICU transfer. Positive predictive value (PPV) was checked by chart review of query results from a pediatric critical care and pediatric hospital medicine physician. Sensitivity was estimated by comparing the query result set to known code blue events on the floor.

2.2 Dashboard Design

We performed interviews with quality and safety leaders to understand tasks related to clinical deterioration improvement. Following a human-centered design approach, we created prototype designs and iterated with prospective users. We continued to test and refine the design throughout the meetings with users to ensure the dashboard would meet the user needs.

2.3 Dashboard Evaluation

We evaluated effectiveness through a survey based on the unified theory of acceptance and use of technology (UTAUT) [2]. We used the UTAUT model because it provides a validated framework that

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helps predict the user acceptance and continued adoption of the dashboard. The UTAUT model also provides insight into the key drivers for acceptance such as usefulness, ease of use, peer adoption and organizational resources or support.

3   RESULTS

3.1   Phenotype Validation

The clinical deterioration phenotype achieved a PPV of 100% on 40 chart reviews. Sensitivity was estimated at 91% with 10/11 code blue events outside the ICU detected. Task analysis identified 3 primary goals to support: (1) tracking the rate of deterioration over time, (2) identifying outliers by care setting or patient characteristics, and (3) identification of the areas with the majority of deteriorations.

3.2   Dashboard Design

The visual analytics dashboard features three key visualizations (see Fig. 1) for monitoring patient deterioration events with filtering and stratification. The three visualizations, each addressing a primary goal, include event counts with rates per 1,000 patient days over time (Fig. 1A), a U-control chart funnel plot for identifying outliers by hospital unit or patient demographic (Fig. 1B), and lastly, a Pareto chart detailing event frequencies and cumulative percentages (Fig. 1C). The visualizations are powered by the two queries developed to detect deterioration, normalized by patient days to generate a rate. The dashboard offers an interactive user experience, enabling details of data points on hover or selecting a data point to focus on a specific area. Outliers on the U-control chart funnel plot are distinctly color-coded, representing data points calculated outside the control limits of 3 standard errors.

3.3   Dashboard Evaluation

The usability of the dashboard was evaluated using a UTAUT survey with 5 participants from our Quality & Safety who had access to the dashboard, had received a demo during a quality data guiding team meeting, and who had used the dashboard at least once. The overall UTAUT score was 4.16/5 with a perceived usefulness sub-score of 4.38/5, perceived ease of use of 4.13/5, social expectancy 4.00/5, and enabling conditions 4.13/5.

4   CONCLUSION AND FUTURE WORK

Human-centered design of a visual analytics dashboard for in-hospital clinical deterioration in children resulted in a highly usable interface. The tasks (tracking over time, outlier identification, and areas of focus) were paired with visualizations (run chart, funnel plot, and Pareto chart), which may be generalizable to many quality improvement projects.

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