'Connecting the dots': leveraging visual analytics to make sense of patient safety event reports

Raj M Ratwani[1,2], Allan Fong[1]

ABSTRACT

An increasing number of healthcare providers are adopting patient safety event reporting systems, yet leveraging these data to improve safety remains a challenge, particularly with large datasets composed of thousands of event reports. A MedStar Health research team, with expertise in data analytics and human factors, developed intuitive visualization dashboards to facilitate data exploration and trend analysis. Dashboards were developed using an iterative design and development process that was end-user focused. A system level dashboard, representing data from multiple hospitals, and a hospital level dashboard were developed. The dashboards allowed users to directly manipulate the data, provided coordinated displays in different formats, and allowed users to quickly zoom in on specific variables of interest. Overall feedback was incredibly positive with nearly all users wanting to adopt the system immediately. Several improvements were suggested and are discussed. The success of this approach highlights the need for more intuitive data analysis tools.

INTRODUCTION

Patient safety event reporting systems (PSRS) provide a framework for healthcare provider staff, including frontline clinicians, nurses, and technicians to report patient safety events.[1] Reported patient events range from 'near misses', where no patient harm occurs, to serious safety events that reach the patient. Reporting systems have the potential to dramatically improve the safety and quality of care by exposing possible weaknesses in the care process.[2] The Institute of Medicine has strongly recommended the use of these systems to identify why patients are harmed by medical errors, and several states require the use of a PSRS.[3,4]

Realizing that the value of a PSRS is largely dependent on the number and quality of events being reported, researchers and practitioners have primarily focused on understanding and developing methods to increase reporting.[5–8] However, an equally important aspect receiving considerably less attention is the development of methods to effectively analyze the reports to 'make sense' of the report data. PSRS can grow to include thousands of case reports, depending on the size of the healthcare provider, and effectively analyzing the report data to make improvements in safety and quality is a significant challenge.[9]

While some PSRS software packages include an analysis component, these capabilities are often limited to basic static graphs of the event data with limited ability to view the data based on variables that may be of interest to the provider organization. Further, the capabilities provided by the software can be difficult to use for the staff that are charged with analyzing the patient safety events. To facilitate the ability for provider staff to understand and act on the PSRS data, our research team has been developing interactive visualization dashboards that allow users to improve their awareness of the types of patient safety events and to dynamically explore and analyze trends. This case report describes the iterative design and development process that is focused on the end-user, the features of the visualization dashboard prototypes, and initial evaluations.

BACKGROUND

MedStar Health is a 10-hospital system serving the mid-Atlantic region and represents a broad spectrum of hospitals and patient populations. The 10 hospitals include large tertiary care/academic medical center hospitals as well as suburban and rural hospitals. Resources total approximately 3300 licensed beds, 5600 affiliated physicians, 166 000 annual inpatient admissions, and 1.6 million annual outpatient visits. In January 2013 a new PSRS was implemented through a third party, which allows any employee to report a safety event by selecting from pre-specified categories and providing details in

For numbered affiliations see end of article.

a structured and unstructured format. Structured data elements include information such as person reporting, patient associated with the report, category of event (eg, medication, fall etc), time of the event, and associated severity level of the event. There have been several thousand reports as of April 2014.

Soon after the introduction of the PSRS, it was realized that the analysis capabilities provided with the PSRS software, which were primarily focused on static bar graphs, provided limited opportunity to understand the data, determine trends, and act on the data to improve safety and quality. An internal research team was formed, with expertise in visual analytics and human factors, to develop patient safety event visualization dashboards to address these challenges.[10–13]

CASE DESCRIPTION AND METHODS: ITERATIVE DESIGN AND DEVELOPMENT

Understanding user needs

Before beginning design and development of the visualization dashboard, the research team conducted multiple semi-structured interviews with the Assistant Vice President of Safety and a project manager from Safety and Quality, to understand the challenges users have faced as they interact with the data analysis component of the PSRS and to understand user needs. Several challenges were identified, such as:

- Extensive training is required on how to use the PSRS system to create reports that show the data in a graphical format.
- Generating graphs requires time consuming queries; this process limits trend analysis and data exploration due to high access cost.
- Graphing options are very limited and many desired comparisons are not available.

The semi-structured interviews also provided insight on the types of questions different users are asking about the patient safety event reports. From the semi-structured interviews the research team identified two core user groups, each with their own unique needs, as described in table 1.

System level users are concerned with high-level information about trends across hospitals, whereas hospital level users are concerned with addressing specific events within their hospital entity. Given the nature of the PSRS data and the needs of the users, a commercially available software package (Tableau Software) was used for rapid development of the dashboards.

Initial prototype design and development

Because each user group has unique needs and a desire to see different aspects of the data, two different prototype visualization dashboards were developed (system level and hospital level). A prominent theme from the semi-structured interviews was the desire to *more easily interact with the patient safety event data*. Thus, the prototypes were developed to allow for direct manipulation, eliminating text-based data queries, so that users could directly click on the visualizations to see the data they desired. This feature also dramatically reduces the training cost of using these dashboards since users no longer have to learn how to submit information queries to access desired data.

Although each of the user groups has different needs, they do share the common goal of seeking specific information, either to answer particular questions they have about the data or to explore trends (eg, How many falls occurred at hospital A and B? Which department has the most severe events?). Consequently, the system and hospital prototypes were grounded in visual information seeking theory and were driven by three visualization principles[14,15]:

- *Overview*: Provide a general overview of the data so that users have awareness of the events and have the context needed to understand the data. For example, the ability to quickly see a breakdown of the severity levels of all events.
- *Zoom and filter*: Allow users to zoom in on specific variables of interest and provide the ability to filter out variables. For example, having the ability to drill down on the most severe events to see where they are occurring.
- *Details on demand*: Allow users to see specific details about particular aspects of the data as needed. For example, the specific number of patient harm events in the emergency department that are fall related.

The initial prototypes for the system and hospital level dashboards are shown in figures 1 and 2. The dashboards allow users to visualize aspects of the data and make comparisons

Table 1: Two user groups and user needs

User	Needs
System level	▶ Improve overall awareness of event types reported at each hospital ▶ Compare rates from the current week to previous weeks ▶ See how the frequency of specific event types differs across hospitals
Hospital level	▶ Focus on the current weeks data to 'take action' on the events ▶ Understand where events are occurring by department and severity level ▶ Share patterns and trends with department leadership to address potential safety hazards

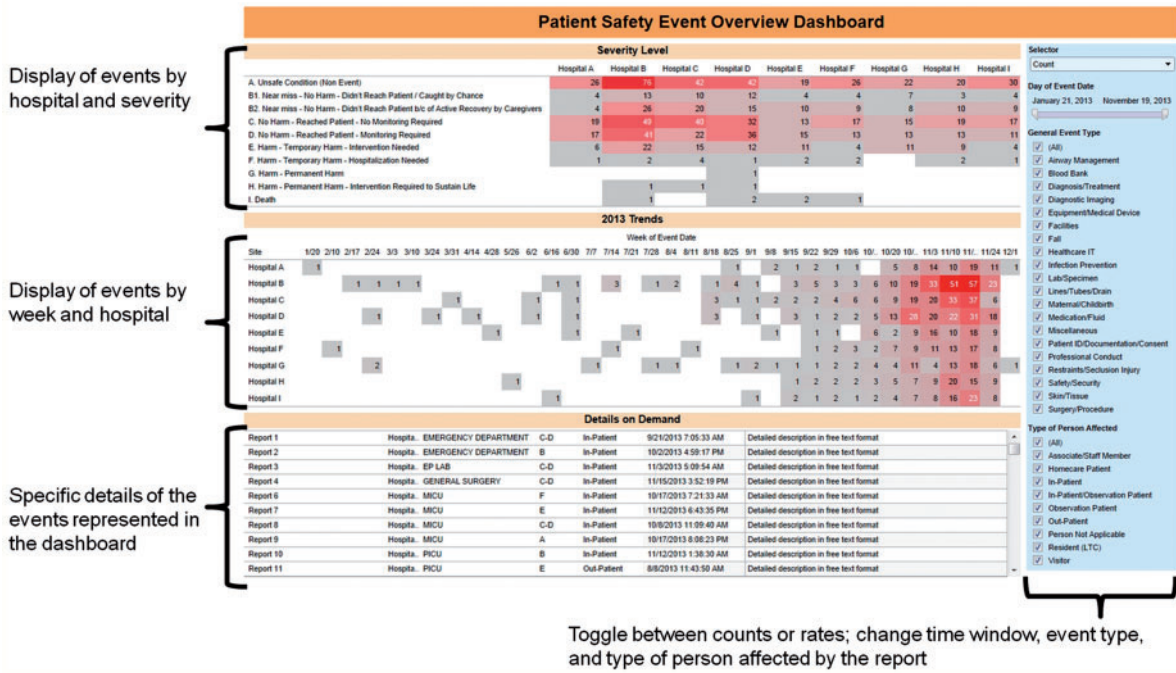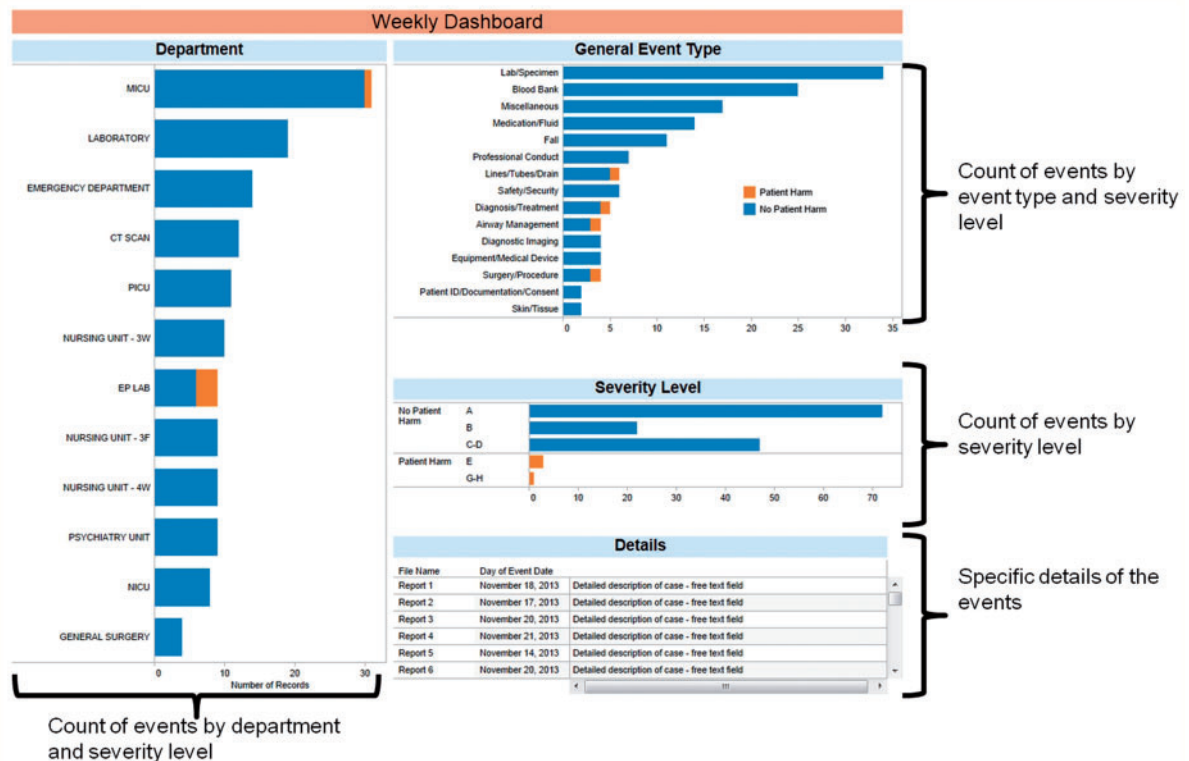**Figure 1:** Prototype system level visualization dashboard.

Figure 2: Prototype hospital level dashboard.

that would not be possible with the current PSRS. All aspects of the dashboard allow for direct manipulation and the distinct panels in each dashboard are coordinated and change dynamically in real-time.[16] A user can select a set of variables or data points to zoom and filter in on their details. This capability provides tremendous opportunity for data exploration and discovery since there is virtually no 'access cost' to seeing aspects of the data that are of interest.

For example, looking at figure 2, a user can highlight the medical intensive care unit (MICU) department from the left panel and the display will dynamically change in real-time to show the event types that comprise the approximately 30 patient safety reports in the MICU. The severity level display (middle right) will adjust to display the severity level of those 30 events and the details panel will show the events' descriptions. Through this process, a user can quickly gain a general understanding of the data and then zoom in on the specific aspects of the visualization that the user finds interesting. Specific details of the cases are always available.

Nearly all of the information that can be extracted from PSRS through data queries can also be extracted from the dashboard visualizations, with the dashboard providing enhanced trend analysis in an intuitive format. However, one limitation of the dashboards is that they do not provide an effective method to search for a specific event based on variables such as keywords or event report number.

User feedback and prototype refinement

The research team conducted focus groups with system and hospital level users to demonstrate the capabilities of the dashboards and to gather feedback for further refinement. Prototype dashboards that were completely interactive and represented a subset of the data were used during the focus groups. At the system level, focus groups were conducted with five participants (including the Chief Medical Officer (CMO), Chief Nursing Officer (CNO), and VP of Quality and Safety). At the hospital level, 13 participants (2 hospital CMOs, 3 hospital CNOs, patient safety officers, department leaders, and nurse leaders) participated in the focus groups from five different MedStar hospitals.

System level and hospital users were incredibly positive about the visualization dashboards and saw tremendous opportunity for trend analysis and data exploration. The 'burden' of accessing the data in a comprehensible format had been dramatically reduced and one system level user called the prototype a 'game changer' because of the ability to rapidly zoom in on important aspects of the data in real-time. Stakeholders at all levels found the coordinated displays and the interactive filtering capabilities very useful and much needed.

System level users felt that the dashboard would improve their awareness of events and would allow them to more easily compare rates of events across the hospitals. Given that many of these capabilities are not available through the PSRS

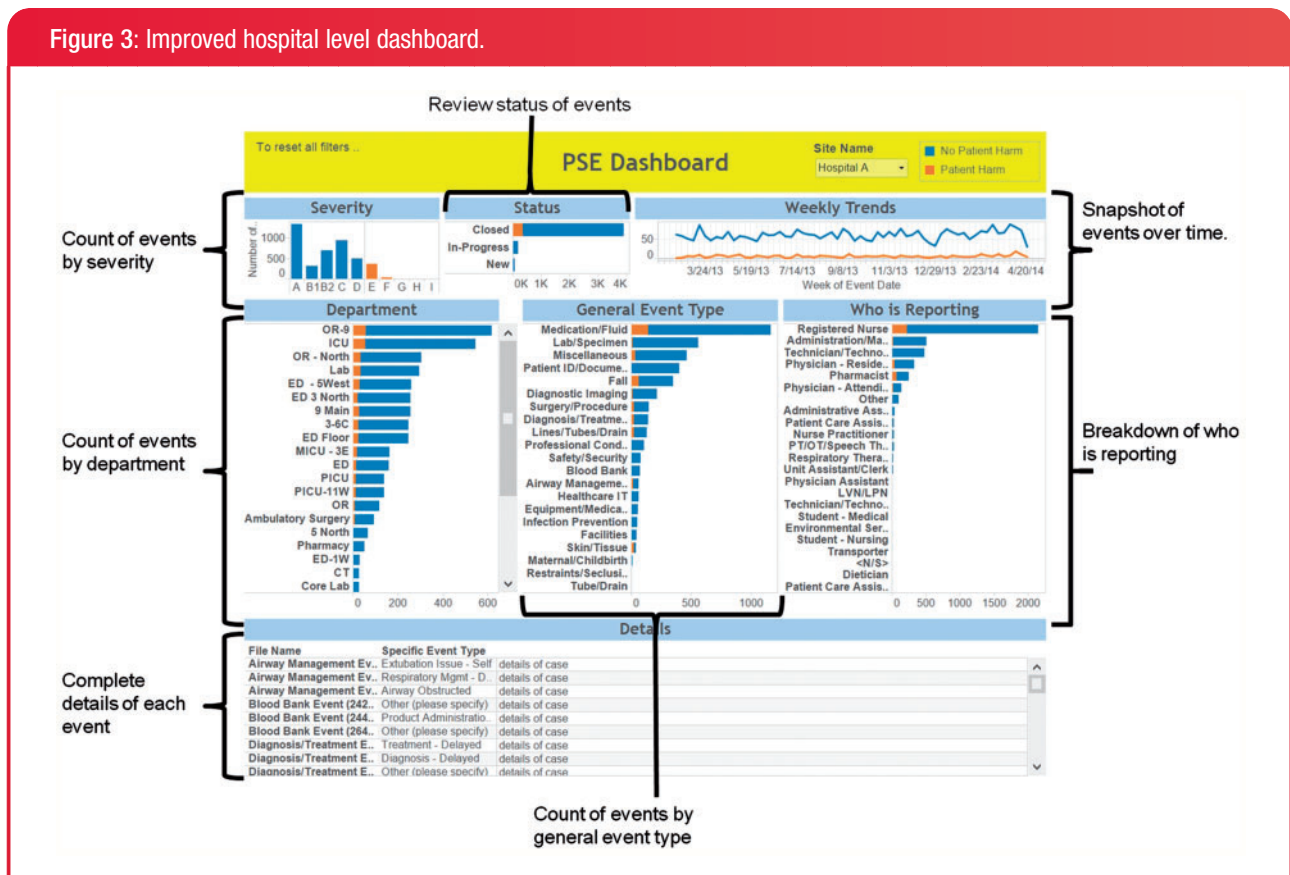**Figure 3**: Improved hospital level dashboard.

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Table 2: Pilot feedback from hospital level users

Identified high value features	Identified areas for improvement
Easy interaction with the dashboard, virtually no training required to interact with the data	Would like to be able to drill down even further into sub-categories of events
Can rapidly see different aspects of the data without submitting new queries	An easier way to visualize the data by quarter for faster comparisons
Details on demand when an interesting trend is discovered	More automated trend detection and highlighting of relevant patterns in the data

analysis component, the system level users had few suggestions for improvement. Hospital level users were impressed with the ability to quickly examine specific aspects of the data that are most relevant to them and to identify 'hot spots'. In addition, these users see the dashboard as a tool that can be integrated with their morning safety huddles and scheduled safety meetings to improve overall awareness of events. The research team also received several suggestions for improvements, primarily from hospital level users. Suggested improvements were centered on including additional variables in the dashboard such as the day/time of the event. Hospital level users, as well as system level users, also wanted to see information on who is reporting and the status of the reports (eg, has the report been reviewed by the department head?). Many of the suggestions, such as visualizing who is reporting and the status of reports, were incorporated into the revised dashboard (see figure 3).

The revised hospital level dashboard was provided to five different hospital level users for a 2-week pilot phase. Pilot users were asked to use the dashboards in place of their normal analysis process that typically involved retrieving graphs from the PSRS system and to provide feedback on the utility of the dashboards. Table 2 shows feedback on features that were found useful and areas for improvement. No formal training was provided to the pilot users. All of the users were able to use the dashboard with simple instructions to click on the aspects of the dashboard to explore the data.

DISCUSSION

The visualization dashboards provide system and hospital level users with a powerful, yet easy to use method, to better understand the numerous patient safety event reports. The dashboards reduce the burden of analyzing the data and, consequently, are likely to encourage greater data exploration and improve the discovery of meaningful trends in the data. Importantly, initial feedback from end-users has suggested that the dashboards will likely dramatically improve overall awareness of events and make the data more actionable. A pilot user provided a concrete example of using the dashboard to quickly assess the extent of a hazard. Given a recent fall event the user interacted with the dashboard to determine how common

'fall' hazards are in a specific department and how widespread this event type is across the hospital to assess the extent of the hazard and appropriately allocate resources. This type of risk assessment would have been far more difficult to conduct without the dashboards.

An early realization by the research team, which will be critical for future development and deployment of the dashboards and other technologies to facilitate the analysis of patient safety event data, is that many of the people within provider organizations that are charged with analyzing patient safety event data do not have extensive data processing and visualization development expertise. Consequently, there is a gap between the 'raw' patient safety event data being reported and visualizations that represent these data in a format that facilitates comprehension and trend analysis. These dashboards are the first steps in filling this void. Several other visual analytic techniques can be leveraged to provide tremendous opportunity for providers to make advances in patient safety and quality based on insights from PSRS data.

CONTRIBUTORS

RMR jointly developed the idea for this manuscript with AF. RMR supported development of the dashboards, led the focus groups and pilot study, and led writing of the original and final drafts. RMR is guarantor of the manuscript. AF jointly developed the idea for this manuscript with RMR. AF led development of the dashboards and supported the focus groups and pilot study. AF is a guarantor of the manuscript.

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AUTHOR AFFILIATIONS

[1]National Center for Human Factors in Healthcare, MedStar Health, Washington, DC, USA

[2]Department of Emergency Medicine, Georgetown University Medical Center, Washington, DC, USA

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