Near-Real Time Monitoring of Reports regarding Patient Safety Incidents in Hospitals using a Web-based Interface

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Abstract

Near-real time monitoring of patient safety incident (PSI) reports can be facilitated with automatic detection methods, which can improve timeliness of detection. Reduced PSI identification time would provide quicker feedback on PSI data to healthcare professionals and allow them to effectively adjust safety procedures at hospitals. A visualization of the PSI data can provide the user with feedback together with a PSI data exploration possibilities and analysis of the PSI patterns. Therefore, a web-based interface (wUI) was developed using web-development tools and provided PSI data from Australian healthcare system as a proof of concept. Usability theory was applied during design to facilitate a user-friendly and intuitive feedback tool. The implemented wUI was validated and the results showed that the systems requirements were fulfilled well, with possible optimization features.

Keywords:
patient safety, incident reporting, web interface, incident statistical output.

Introduction

Millions of patients worldwide have experienced deaths or disabling injuries due to errors in the healthcare system [1]. The World Health Organization (WHO) estimates that adverse events accounts annually for 850.000 PSI in the United Kingdom Department of Health. In the developed world around 10 % of all hospital admissions involve a patient incident of adverse character with one out of three incidents leading to patient death or disability [1, 2]. Medical errors are between 5th to 8th leading causes of death in the U.S. and the annual costs of patient safety incident (PSI) are approximate \$38 billion [3–5]. Therefore, to overcome errors, healthcare systems need to learn from errors, with PSI reporting systems as a key tool to improve patient safety [6–8]. PSI systems have the potential to share and highlight trends and patterns in incident data and to detect potential emergency problems in near-real time [9, 10]. The fundamental challenge is to convert the large data set into comprehensible information, which could enhance response to patient safety problems as they emerge [9].

Background

When an incident occurs in a hospital, it is necessary to prevent reoccurrence. To benefit from the patient safety incident, a description of the event is required to an electronic incident reporting system. Therefore, a PSI report includes both a documented description and categorization of the incident event [11]. Since the structure of PSI reports varies between hospitals, the information from PSI reports needs to be extracted and classified into different types of incidents and levels of severity using Severity Assessment Code (SAC) [12, 13]. There are 20 different incident types in the incident management system used in the New South Wales public hospital system, for example falls, clinical management, medication/IV fluid, documentation etc. [14]. The SAC levels describe the severity of the incident from high risk (SAC 1) to low risk (SAC 4) and are based upon two categories: likelihood and consequence [15].

Voluntary reporting of PSI is a valuable source for studying and analyzing patterns of adverse events and near misses to prevent PSI reoccurrence and improve safety [16]. Therefore, the PSI reports are important means for identification of errors in the healthcare system. However, the reporting system has limitations and critical areas [17]. Utility and data collection systems, used for evaluation of PSI are negatively affected by an inconsistency in language, incompleteness and lack of accuracy in the reported data [13, 16]. Furthermore, several problems associated with incident reporting are e.g. participation bias, problems with form completion or with correct classification, but also lack of reporting the incident [17, 18].

Over 40% consultants (specialist doctors) and registrars have never submitted an incident report. Around 25% of hospital staff did not know how to access an incident report form. Only small percentages of doctors actually completed the incident report [18]. The possible reasons for lack of reporting include time pressure, unfamiliarity to the process, fear of blame, an approach that it is unnecessary to report, possibility of reports ending up in a “dark hole” and resource constraints. Additionally, workplace discrimination, fear of punitive action and legal ramification because of cultural issues may contribute to the lack of reporting incidents. However, the main problems related to incident reporting are probably the conception, that only bad doctors make mistakes, and a lack of clarification about what should be reported [18, 19]. Moreover, primary barriers for not reporting PSI might be issues related to an inconsistent language due to variety of the used terms and the lack of feedback [13, 16, 18]. An existing lack of feedback from the PSI reports is the main reason for lack of reporting [19–21]. It is reported that 2/3 of the respondents named the lack of feedback as the main obstacle for not reporting PSIs. However, by using newsletters or other feedback methods, the rate of reporting increased [18–20]. Therefore, mechanisms and forms of an effective feedback from PSI reporting were researched by Benn et al. [19]. The results revealed, that a feedback incorporating multiple modes of both information and action processes, would be the most beneficial for patient safety and risk management systems. Furthermore, the feedback must include corrective safety actions and be closed in order to ensure, that the vulnerabilities identified from reporting, analysis and investigation are timely and correctly addressed in the environment at the healthcare [19]. In a study by Ratwani et al., a system level dashboard was developed to provide users with a visualization tool for the PSI to improve accessibility and awareness of PSI data [9]. The dashboards reduced burden of analyzing data and encouraged the data exploration [9].

Therefore, to improve the means for giving feedback, a web-based interface (wUI) was developed and described within this study. The wUI builds upon previous studies, which have demonstrated feasibility of statistical text classification to identify PSI types and severity [10, 22, 23].

Methods

Understanding of the IT systems and procedures in the Australian healthcare system was considered as important for the system development process. Therefore, an interview was performed with the Patient Safety and Quality Unit of a teaching hospital attached to the University, in order to gain practical knowledge about healthcare providers, reporting procedures and a familiarization with one of the Australian PSI reporting systems. The outcome of the interview together with guidance related to PSI research from the Centre for Health Informatics helped the researchers to perceive the structure of the PSI reports, system and data presentation.

System Description

The developed web-based user interface (wUI) provides assistance with PSI monitoring for the healthcare professionals and researchers (Figure 1). The obtained information from wUI can ensure the quality of the patient safety in the healthcare system and improve means of the given feedback to the reporting healthcare professionals.

The feedback provided by the wUI gives a quick insight and an overview of the reported PSI data. To aid monitoring and trend analysis of PSI data, a near real-time tracking of the PSI data can be added to the wUI.

The wUI can be accessed through the Internet and has no specific system requirements. Therefore, healthcare professionals can easily and quickly use it at any time and on any devices. To achieve a positive user experience, design elements are implemented with respect to usability theory and similarity to the existing PSI reporting systems in the Australian healthcare system. The usability describes the connection between the user's needs and the behaviour, and not the design choices, e.g. in the user interface (UI) [24]. Usability requirements in relation to healthcare system include: matching of real world and system, providing informative feedback to the user, clearly defined user control, error prevention, keeping consistency, use of minimalistic and intuitive design, easy to understand error messages and system can be used by both experienced and inexperienced users [25-27]. Functionality of the wUI includes monitoring, exploration and visualization of the selected PSI data. The possibility of selecting a specific PSI data, gives the user an opportunity to obtain a visualization and information about specific PSI prevalence and trends based on the chosen PSI incident types, SAC levels and time range. An example of the visualized PSI data in Incident Data UI is shown in Figure 1. The user has a chance to zoom in on the plotted PSI results, see highlights of the PSI data and filter the results from the graph, as shown in Figures 2-4. Additionally, the wUI allows users to learn about patient safety quality improvement, research programs and provides contact information to the research center. Due to the privacy restrictions and data safety requirements, the access in the wUI to some of the elements is limited to the registered users.

System Development

A sample of processed PSI data, i.e. output of statistical text classifiers was used to develop and validate the wUI [10]. The received PSI data was imported to the local MySQL database (MAMP 3.0.6 with phpMyAdmin 4.4.1) to allow manipulations and extraction of the PSI data using SQL syntax. To program connections and communication with the server and MySQL database, a Hypertext Preprocessor (PHP) was used and was also responsible for collecting the PSI data and controlling the login session.

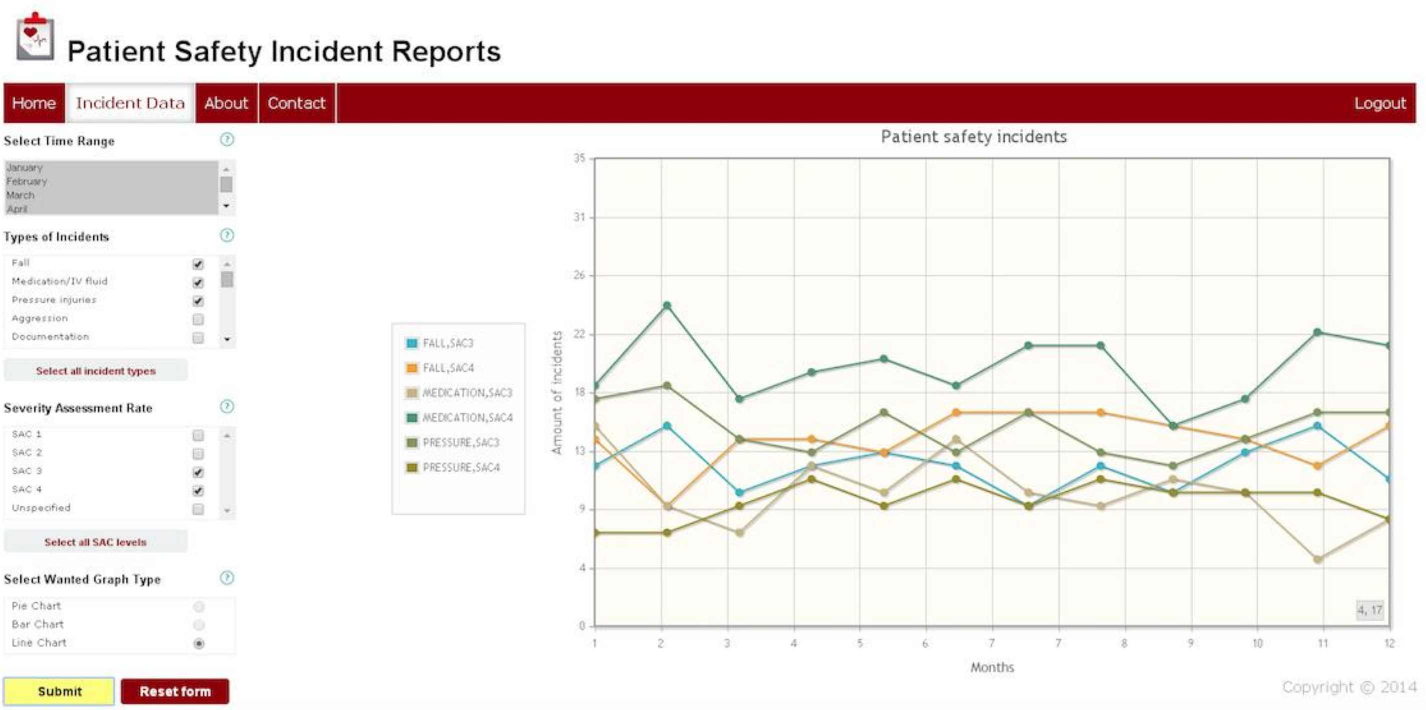

Figure 1 - Incident Data UI with the visualized PSI data

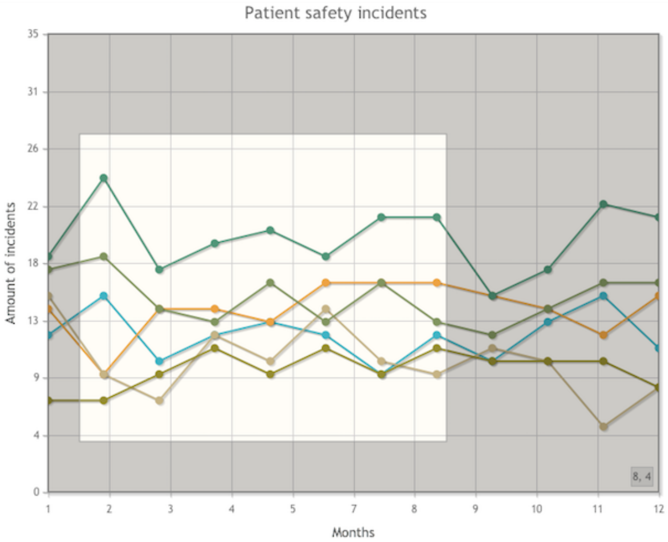

Figure 2 - Zoom

The development process of the wUI consisted of iterations and constant adjustments. Elements of both the Unified Modeling Language (UML) and Unified Process (UP) were used to document the development process of the system. To represent functionality of the wUI, functional and non-functional system requirements were specified. The requirements were further used for the analysis and design phase, where the architecture for the wUI was developed. Proposed design of the wUI was adapted to fulfill the usability requirements to achieve a user-friendly and intuitive layout. The visual aspects of the wUI were based on the gathered knowledge from the interview with the Patient Safety and Quality Unit in an Australia private hospital and guidance from the Centre for Health Informatics.

The wUI implementation of the identified elements was achieved using several web-development tools. The implemented wUI consisted of eight UIs: Home, Incident Data, three About, Contact, Login and Forgotten Password. Each individual UI consisted of architectural structure elements, which were accessed and manipulated with use of a HyperText Markup Language (HTML). The Cascading Style Sheets (CSS) was used to describe and give a consistent graphic design over all of the UIs. Two CSS files were created, where the different HTML elements' appearance and content were defined and described. User interactions with the wUI and a functionality of HTML elements were coded and defined in JavaScript (JS). Since the wUI should work on different web-browsers, a JS library called jQuery was mainly used for programming of wUI functionality. The jQuery allowed to make an Asynchronous JavaScript and XML (AJAX) request, which processed the selected PSI data from the form in the Incident Data UI and its visualization in the UI by updating only the graph and without reloading the whole UI. The PSI data was stored and exchanged a JavaScript Object Notation (JSON), and was further processed in jQuery for visualization of the PSI data using a jQuery plugin called jqPlot.

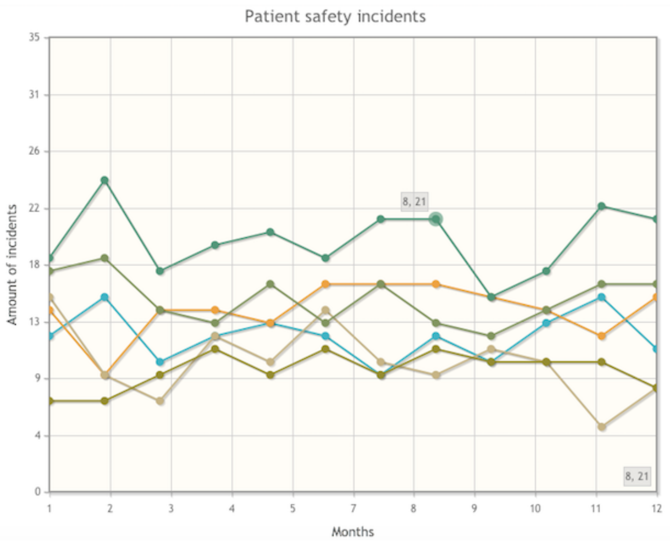

Figure 3 - Line marker

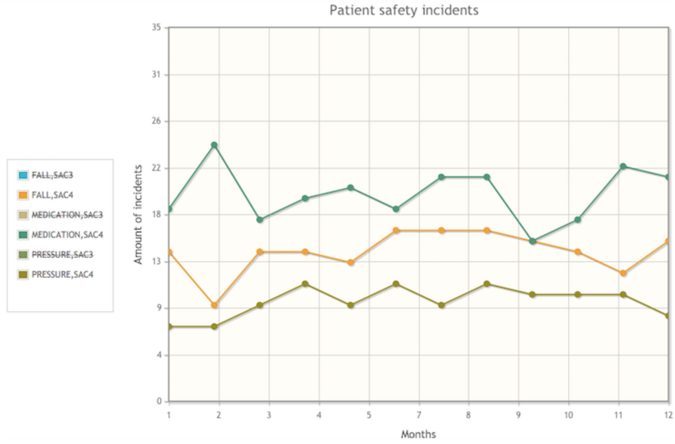

Figure 4 - Selected/deselected PSI data

During the implementation process of the wUI, iterative tests identified and allow correction of possible errors early in the implementation process. Performance tests were performed on the developed wUI according to a test protocol, to identify missing functionality and verify error prevention methods.

System Validation

Validation of the system is completed by verify the proposed solution using a usability and design validation, that was performed with three researchers from the Australian Institute of Health Innovation. The participants had wide knowledge and different perspectives of healthcare. Age of the participants varied to validate utilization of the wUI by users with different IT skills.

The participants were asked to perform tasks specified in the validation protocol, which were related to the use of wUI. Then the participants were interviewed by the researchers regarding evaluation of functionality, design, intuitiveness and user friendliness of the wUI with focus on visualization of the PSI data. The evaluation was conducted based on questions aimed to determine if implemented design choices fulfilled the specified requirements for the wUI. After the evaluation, possible improvements of the wUI were investigated.

The presented validation results included both positive and negative feedback about the implemented features and design choices. Missing features, which implementation would benefit the wUI, were collected as a list of possible optimization of the wUI ideas. Some of the validation results are presented in Table 1.

Table 1 - System validation results of the wUI.

Positive Feedback	**Negative Feedback**	**Missing Features**
Clear and simple design Easy navigation Understandable visualization Plot provides correct information PSI data given in perspective Helpful highlighter	Visually difficult to read text Lack of plot instructions Hard plot interpretation with lots PSI data Disturbing/not visible pop-ups	Print/Export button Selection of hospital/depart-ment/ward Sum of all SAC levels for plot Hoover bubbles instead of pop-ups Add bar, pie and stack graph types Assign a color to an incident

Discussion

The wUI was chosen to be a web-based interface, which can be used at several healthcare organizations. The chosen form for the interface was based on a need for a system that can be easily accessed by the user, as documented by Ratwani et al. [9]. The system developed as a web-based interface has no specific technical requirements, such as hardware, software and installation programs, which are needed for the wUI to work correctly. Therefore, the system can be used as an aid system at healthcare centers without influencing existing IT structures and systems. Additionally, maintenance of the system will be easier, since the user will not need to speculate about checking and installing possible updates for the system. Instead, the wUI programmers will apply updates, improvements or patches for the wUI and the users will automatically always use the newest version of the wUI.

Due to system implementation as a website and connecting it to the database, the near-real time monitoring and updating of the database is possible for all of the users. Behind the presentation layer, implementation of an algorithm, which would automatically process data, would improve incident identification and provide a quick update on the identified incident patterns. Moreover, statistical tools would be needed to monitor the database and indicate to the user, when new or alarming results are becoming available. The developed version however, does not have the algorithm implemented and only functions as a proof of concept on the extracted PSI data. Different types of automatic classifiers can be used for wUI. It does not matter, which classifier type processes the PSI data, because visualization method of the PSI data is still the same in the wUI. An example of an automatic classifier was described in a study by Ong et al., where a feasibility of automatic classifiers to monitor large amounts of incident reports and detection of extreme-risk events was researched [23]. Furthermore, such types of classifiers allow discovering new knowledge about the reported incidents from the large-scale descriptive incident text.

The validation of the implemented wUI was performed to investigate how well the usability principles were implemented. It was important that the final system would be user-friendly and intuitive, because the chances of a successful implementation of wUI in the healthcare would increase. The familiar design will help the user to avoid confusion and fear of how to use the system, since the adaptation process would be easier. Moreover, the system's functionality should be broad and give the user a possibility of the PSI data exploration. The researchers from validation group had different expertise field, which allowed gathering opinions about the wUI from three perspectives. Their comments were useful for future improvements of the system. However, the validation points are given from the researchers' point of view, which may differ from the healthcare professionals' and their expectations. Due to time constraints, which did not permit an opportunity to obtain ethical approval, the validation of the wUI at a healthcare center was not performed. However, if the ethical approval for the wUI validation at a healthcare center could be obtained, it would be feasible to conduct a validation of the wUI at the healthcare center.

The validation results proved that from the graphic design angle, the wUI was designed in a clear and simple way. There are thus documented navigational problems, especially at Incident Data UI, where two out of three participants commented that they lacked information about how to plot the PSI data, which selections are needed and how to select the PSI data. Therefore, help information for the user about the use and limitations of the system would be work in future.

Some of the visualization functionality was found missing. Mostly the requested functionality was concerning specific or missing graph types. Another comment regarding an additional functionality was to implement print and/or send the plot options. Those features would be helpful, if the user would like to share the data with others, but can cause security and privacy concerns, if the data would be send to someone without access to the wUI. It is possible to implement these functions, however some limitations should be added to prevent unauthorized access and compromising the confidentiality of the PSI data.

Several comments regarding readability of the data were provided and all of the persons in the validation group commented on the lack of larger variety of colors for the plot. A suggestion of attaching a specific color to an individual incident was made. To make the plot even more readable, a possibility to see a sum of SAC levels for the individual incident type would be beneficial. By applying those three comments, the visualization and readability of the PSI data would increase, since it would be more intuitive for the user.

The provided PSI data included number of incidents from different departments at the hospital. To enrich the information and provide the user with additional option for more specific PSI data search, the possibility of choosing hospitals, wards or departments was suggested. It could be beneficial for a user, which would like to obtain a very specific PSI data. However, it would reduce the anonymity of the reporting healthcare staff, since one would have access to a very detailed data, which could be misused by the user. A small overview of the PSI data would not reflect the major problem with the PSI, since the user would only receive a feedback on a small area of data and consider some of the incidents as not significant and by looking at the broader scale would prove to be crucial. Therefore, implementation of the wUI on the broader - regional, national, international - scale would provide more benefits and a better overview of the PSI problem. The user would then have a chance to explore broader scale of data and the PSI data would remain anonymous.

Conclusion

The wUI was developed as a proof of concept to provide healthcare professionals with feedback about PSI reports and visualization of patterns. By visualizing the PSI data, data exploration is possible highlighting trends and patterns in the PSI data. The patterns can be used to bring focus on safety issues in healthcare organizations. System usability was evaluated and was proved to be well carried out in the wUI design choices. The validation helped with identification of the missing functionality, which is advised to be implemented in the wUI. After implementation of the missing functionality, the developed wUI has a possibility of being implemented in a regional, national and international scale to detect potential patient safety and emergency problems. Moreover, the connection to the database of the wUI results potentially in establishing a near-real time monitoring of the PSI data, which could provide the healthcare professionals with almost immediate feedback on the PSI.

Acknowledgments

This research was supported by the Australian Institute of Health Innovation and was undertaken during Mia Horsboel Hansen and Marlena Anna Plocharska's research visit to the Institute in 2014. Mia Hansen's and Marlena Plocharska's travel and accommodation expenses were supported by Nordea foundation (Denmark), Knud Hoejgaard foundation (Denmark), Otto Moensted foundation (Denmark), Torben and Alice Frimodts foundation (Denmark), Oticon foundation (Denmark), AAU Internationaliseringspulje foundation (Denmark) and Fabrikant Aage Lichtingers scholarship (Denmark).

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