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From Data to Decision: Design and Evaluation of a Patient Safety Dashboard

Mahni Mehdibagli[1]*, Reza Safdari[2], Mahboobeh Mirzaee[2]

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Abstract

Background: The global healthcare landscape is undergoing a significant transformation, and healthcare systems are operating in increasingly complex environments. Nevertheless, patient safety remains a central concern in hospital-based care. Current patient safety measurement approaches are primarily based on practices originating from the predigital era. In contrast, health information technology offers a promising and viable solution to address this critical need. Therefore, this study aimed to design and evaluate a patient safety dashboard.

Methods: This descriptive developmental study was conducted in 3 phases. Phase I included a literature review and a 2-round Delphi survey with 60 patient safety experts to identify and validate indicators (questionnaire reliability: Cronbach's alpha = 0.91). Phase II involved designing the dashboard using QlikView and FreePlane software, integrating data in Excel, and developing visual and functional features. Phase III involved evaluation by an IT specialist using a structured framework and usability testing with ten end-users, conducted via the System Usability Scale (SUS).

Results: A total of 62 key patient safety indicators were identified and classified into 8 main categories. These indicators were integrated into a prototype dashboard with a hierarchical structure enabling multidimensional analysis and interactive visual features. Evaluation showed an overall compliance rate of 80.92% across dashboard design criteria, with the highest compliance in architecture, layout, and analytical features (100%). Usability assessment using the SUS among 10 users yielded an average score of 82.99, indicating high user satisfaction.

Conclusion: This study developed and evaluated a patient safety dashboard to support clinical decision-making. The dashboard facilitates monitoring safety incidents, root cause analysis, and trend comparison over time. Evaluation using a structured framework confirmed the design quality and usability of the system, highlighting its potential to improve continuous patient safety monitoring and outcomes in healthcare settings.

Keywords: Dashboard, Patient Safety, Patient Safety Indicators, Design, Evaluation, Data Visualization, Decision-making

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Introduction

The global setting of healthcare is undergoing a significant transformation, and healthcare systems function in increasingly complex environments (1). Nevertheless, patient safety is a significant concern in hospital-based care (2), and safety-related failures continue to impose significant economic and financial burdens (3). Since the publication of a landmark report in 2000 by the National Institute of Medicine titled "To Err is Human: Building a Safer Healthcare System," the patient safety debate has received unprecedented attention from both the general public and the healthcare industry

Corresponding author: *Mahni Mehdibagli, Mahni.mehdibagli@gmail.com*

1. Department of Health Information Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran
2. Health Information Management and Medical Informatics Department, School of Allied Medical Sciences, Tehran University of Medical Sciences, Tehran, Iran

↑What is "already known" in this topic:
Despite extensive global initiatives, there are significant challenges in patient safety, and conventional measurement methods are often outdated and underutilize digital capacities. Dashboards are increasingly employed in clinical settings to display patient safety indicators, enhance data visualization, and support systematic monitoring and communication.

→What this article adds:
This study designs and evaluates a patient safety dashboard using a structured and user-centered approach. It provides empirical evidence on the dashboard's usability and its potential to enhance patient safety monitoring and support clinical decision-making in healthcare settings.

(4). This report was meant for widespread collection, analysis, and application of healthcare data for improving patient safety across healthcare organizations (5). Efforts to reduce the burden of patient harm have not resulted in substantial systemic changes over the past 15 years, despite global initiatives and preventive strategies implemented in certain healthcare institutions (1).

In recent years, the improvement of hospital quality and safety has been on the global healthcare agenda (6). Over the past decade, healthcare systems have experienced rapid digital transformation, particularly through the widespread implementation of Electronic Health Records and electronic imaging systems. However, major patient safety challenges persist, including the measurement and prevention of diagnostic errors, medical mistakes, adverse events, unintended injuries, and other forms of preventable harm (7). Although fundamental for improvement, the existing patient safety measurement approaches are still primarily based on practices from the pre-digital era. Voluntary incident reporting and manual root cause analyses remain the predominant methods; however, they rarely integrate or capitalize on the capabilities offered by modern digital infrastructures (7). As Sheikhtaheri et al stated, "Improving reporting system usability, reinforcing support structures, enhancing perceived benefits and performance outcomes, and increasing managerial support facilitate greater acceptance of Patient Safety Reporting Systems among nurses" (8).

Growing evidence of preventable deaths caused by medical errors has led to renewed calls for more effective and accurate safety measures in hospitals (9). To achieve this goal, patient safety can be measured quantitatively using patient safety indicators (PSIs), which serve as metrics to track adverse events and medical errors, primarily aiming to establish a data-driven system for monitoring patient safety (10). Accordingly, leveraging health information technology offers a promising and viable solution to address this critical need (9).

Improving patient safety necessitates a structured framework that encompasses the identification of safety events and root cause analysis, the development of corrective actions, the implementation of improvements, and the receipt of feedback on outcomes. In Iran, there is a scarcity of reliable data on medical errors, with available information derived from case reports, medicolegal data, and patient complaints (11). Nonetheless, it is estimated that approximately 24,500 individuals die each year as a result of medical errors (12). To address this gap, a set of 29 patient safety indicators tailored explicitly for the Iranian healthcare context has been developed to support standardized monitoring and improvement efforts (10).

A dashboard is a data-driven clinical decision support tool that can query multiple databases to provide a visual representation of key performance indicators in a single report (3). Dashboards have been extensively used both within and outside the healthcare sector, serving as a form of visual data display, enabling efficient dissemination of information (5). In clinical settings, dashboard integration aims to improve communication regarding patient safety and facilitate the detection and management of safety concerns (2). In the context of patient safety, dashboards are utilized to highlight trends and metrics related to complications, adverse events, and medical errors. The electronic presentation of aggregated data on dashboards is collectively known as Business intelligence (BI) (13).

Recently, there has been growing pressure to develop standardized patient safety metrics to assess healthcare system performance (13). Unlike qualitative, case-based approaches, the use of PSIs introduces a quantitative perspective, enabling more consistent reporting and analysis of safety outcomes (14). In this context, dashboards, as a branch of balanced scorecards, have been increasingly recognized as a tool for presenting KPIs to support decision-making. Dashboards have been progressively employed as a benchmark tool for mandatory reporting on meaningful use as well as for regulatory purposes (13).

Drawing on previous literature, stakeholder involvement, and iterative design methods, this study aimed to design and evaluate a patient safety dashboard that facilitates the monitoring and communication of safety-related data. This work presents a practical approach to developing dashboards that can enhance performance, productivity, and service quality in healthcare settings.

Methods

This descriptive developmental study was conducted in three phases as follows.

Phase I: Identifying Key Performance Indicators for Patient Safety

This descriptive phase of the research aimed to determine the key indicators of patient safety. Specifically, it involved a review of academic literature through searching major databases, including PubMed, Scopus, Web of Science, and Google Scholar using keywords such as "patient safety indicator," "patient safety index," "PSI," "patient safety measure," and "quality indicator" to extract and categorize patient safety indicators from organizations providing these metrics. The qualitative aspect of the study consisted of this literature review, and the identified indicators were selected and validated through a two-round Delphi method, forming the quantitative component of the research.

To extract the key performance indicators for this study, the patient safety indicators from AHQR were used. (15), OECD (16), ESQH (17), as well as those from Australia (18), the UK (19), and Canada (20) were utilized. All indicators were reviewed and extracted, which were subsequently validated through a questionnaire distributed to 60 experts in the field of patient safety, mainly from the patient safety and quality improvement units of public hospitals affiliated with Tehran University of Medical Sciences. The validation process was carried out in two rounds using the Delphi technique. Sampling was not necessary due to the limited size of the research community. The content validity of the questionnaire was confirmed with the assistance of 5 experts, and its reliability was verified using the test-retest method over a 2-week interval with the same experts. Internal consistency was also demonstrated by a Cronbach's alpha of 0.91. The acceptance criteria for the

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indicators were as follows: indicators with a mean score >3.75 in the first Delphi round were accepted; those with a mean between 2.5 and 3.75 were re-evaluated in the second round; and indicators scoring <2.5 were excluded.

In this phase, the experts not only assessed the importance of each of the identified indicators, which were characterized based on the Likert scale, but also added any additional relevant indicators not included in the questionnaire. After the two-round Delphi process, 62 key patient safety indicators were identified and categorized into eight main groups as follows: obstetrics, surgery, mortality, infection control, medication error, hospital fall, Patient Safety Friendly Hospitals Indicators, as well as other specialized indicators."

Phase II: Defining the Overall Architecture, Design, and Development of the Patient Safety Dashboard

This phase of the research was developmental in nature. It aimed to design and develop the dashboard through four key steps: defining the overall architecture, creating the database, uploading data into the dashboard, and establishing the visual and functional features of the dashboard using QlikView software.

1. Determining the Architecture and Designing the Information Map of the Dashboard

An information map was created using FreePlane software to determine the dashboard architecture and its layers, as well as to represent the relationship between each indicator and the influencing components. In the first layer of the dashboard, patient safety indicators were presented in eight groups, while the second layer displayed the subcategories for each group. Subsequent layers contained the detailed information for each indicator.

2. Creating an Integrated Data Repository and Uploading Data into the Dashboard

To establish communication and integrate data sources with the dashboard, data aggregation and organization were performed in the form of an integrated repository (Excel format). A hierarchical format was employed to accommodate the need for a multidimensional representation of the indicators.

After organizing the data in the Excel format and calculating the indicators, the data was uploaded into the dashboard environment.

3. Designing the Functional and Visual Features of the Dashboard

3.1. Functional Design

During the functional design phase, aspects such as the ability to display temporal trends, analytical capabilities to assess status through color-coded and visual alerts, detailed drill-down capabilities, and multidimensional representation of indicators were considered. Enabling users to select display methods based on their preferences, as well as the flexibility, interactivity, and visual customization of the dashboards, were also prioritized. Furthermore, the incorporation of predictive analytics capabilities was a key consideration.

3.2 Visual Design

The visual design focused on defining the key components of the dashboard, including charts and tables, selecting appropriate color schemes, arranging elements for optimal readability, and structuring dashboard layers to enable drill-down functionality for in-depth data analysis.

4. Designing and Developing the Dashboard

The dashboard was designed and developed within the QlikView environment, namely a software platform for data integration. With its capabilities, QlikView enables users to visualize and explore data from various sources in different formats, thereby facilitating data-driven decision-making.

Phase III: Determining Key Criteria for Evaluating the Patient Safety Dashboard

In this phase, the evaluation was conducted using 2 methods. The first method involved assessing the dashboard requirements based on the evaluation framework proposed by Dyczkowski et al (9), which encompasses a comprehensive review of various elements, including dashboard design specifications, KPI requirements, information presentation, architectural structure, layout design, alert mechanisms, user interactivity, display features, data delivery methods, and analytical functionalities (Table 1).

Information Technology (IT) specialists performed this evaluation with expertise in dashboard design and development. The second method focused on assessing usability from the end-user perspective using the System Usability Scale (SUS) questionnaire. Ten staff members carried out this assessment, and supervisors working in patient safety or quality improvement units at hospitals affiliated

Table 1. Assessment of Dashboard Design Requirements

Requirement Category	Requirement Details	Present	Absent
Dashboard Design requirements	formatting templates for consistent look	✓	
	WYSIWYG design mode	✓	
	Structure mode for faster design without all data	✓	
	Record limit in design mode		✓
	Undo	✓	
	Java development environment or Visual Studio or SDK for embedding		✓
	Developer-defined scales for data not in data warehouse	✓	
	Elements re-usable in multiple dashboards	✓	
	Web-based design environment	✓	
	Ease of design and maintenance aspects	✓	

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Table 1. Assessment of Dashboard Design Requirements

Requirement Category	Requirement Details	Present	Absent
Presentation requirements	Conditional formatting - traffic lights, trend arrows, highlighting of exceptions and variances within tabular display	✓	
	Charts Overall	✓	
	Hi/Lo Chart		✓
	Gauge Chart	✓	
	Bullet Graphs	✓	
	Spark Lines	✓	
	Maps		✓
	Ability to create own visualizations	✓	
Alerting requirements	Alerts - Visual display of exception values or text	✓	
	Alerts - Email notification	✓	
	Alerts - user defined in addition to centrally defined	✓	
	Alert as RSS feed or textual display within dashboard		✓
Analysis requirements	This Year/Last Year analysis	✓	
	Top 10 ranking	✓	
	Asymmetrical reporting (expand Q4, collapse Q1-Q3) Predictive analysis / what if 0 2	✓	
	Predictive analysis / what if	✓	
	Advanced analysis (based on data exploration)	✓	
Dashboard Layout requirements	Multiple objects on a page/display	✓	
	Ability to resize portal objects independently	✓	
	User defined dashboard layout, in addition to centrally built by	✓	
	Multiple data sources within dashboard presentation	✓	
KPIs / metrics requirements	Web-based screen for users to enter target for KPI		✓
	Multiple targets per metrics (stretch goals)	✓	
	User-defined KPIs	✓	
	IT-developed KPIs as part of dashboard	✓	
	Predefined KPIs / metrics dedicated for managers	✓	
	Web-based screen for users to enter target for KPI	✓	

Table 1. Assessment of Dashboard Design Requirements

Requirement Category	Requirement Details	Present	Absent
Dashboard Interactivity requirements	Global filter for all gadgets in dashboard	✓	
	Re-sort data in a table within an existing dashboard	✓	
	Drill-down	✓	
	Pivot / drill by other dimensions		✓
	Drill from one dashboard to another with context passed		✓
	Sliders / Lassos to select content	✓	
	Flash animation		✓
	Overall usability and navigation	✓	
Architecture requirements	Caching - consistently fast response time	✓	
	Auto refresh/requery of dashboard objects	✓	
	In-memory	✓	
	Web-based dashboard delivery	✓	
	Broad and Flexible data access (OLAP, relational, Web-Services, deep Internet)		
	Dashboard integration with other tools in the BI Suite	✓	
Delivery and other requirements	Print whole dashboard	✓	
	Export to PDF	✓	
	Export to Excel	✓	
	Disconnected access		✓
	Live Excel connectivity	✓	
	Guided analysis / workflow / link reports	✓	
	Annotations /Collaboration		✓

with Tehran University of Medical Sciences (21).

Results

The results are presented based on the developmental phases of the study. In the first phase, as summarized in Table 2, a total of 62 key patient safety indicators were identified and categorized into eight main groups. Expert evaluations, conducted using a 5-point Likert scale, revealed that all categories received average scores above 4, reflecting their perceived importance. The mean scores were as follows: obstetrics (4.80), surgery (4.90), mortality (4.93), infection control (4.89), medication errors (4.87), falls (4.91), patient safety in a friendly hospital (4.70), and other specialized indicators (4.85). Based on these results, all indicators were approved for inclusion in the dashboard.

In the second phase, the architecture of the dashboard and its multilayered structure were defined using an information mapping approach developed with Freeplane software. Mapping facilitated the visualization of relationships between each patient safety indicator and its contributing components. In the first layer, the indicators were categorized into eight groups, followed by a second layer detailing the subcategories within each group. Subsequent layers provided comprehensive specifications for each indicator.

To construct the prototype of the patient safety dashboard, QlikView—a data integration and visualization tool—was employed. A centralized data repository was developed in Excel format to support the integration pro-

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Table 2. Selected Indicators for Monitoring in Patient Safety Dashboard

Group of indicators		Indicator
Obstetric-Related Indicators	1	Birth Trauma – Injury to Neonate
	2	Obstetric Trauma – Vaginal Delivery with Instrument
	3	Obstetric Trauma – Vaginal Delivery without Instrument
	4	Cesarean section-related trauma
	5	Obstetric complications
	6	Obstetric Trauma– Patient fall
	7	In-hospital fall or hip fracture in obstetric patients
	8	Postpartum hemorrhage
Surgery-Related Indicators	9	Foreign Body Left in During Procedure
	10	Complications of anesthesia
	11	Unplanned Return to the Operating Room
	12	Postoperative Hemorrhage or Hematoma
	13	Postoperative Respiratory Failure
	14	Postoperative Pulmonary Embolism or Deep Vein Thrombosis
	15	Postoperative Sepsis
	16	Accidental Puncture or Laceration
	17	Wrong-site surgery
	17	Medical equipment-related adverse event
	19	Postoperative complications
	20	Postoperative Hip Fracture
	21	Postoperative Physiologic and Metabolic Derangement
	22	Postoperative Wound Dehiscence
Mortality indicators	23	Hospital Standardized Mortality
	24	Death in Low-Mortality Diagnosis Related Groups (LM-DRGs)
	25	Preventable Deaths
	26	Amenable mortality from surgical complications
	27	Neonatal Mortality
	28	Maternal Mortality
Infection control indicators	29	Nosocomial Infections
	30	Selected Healthcare-Associated Infections (Selected HAIs)
	31	Surgical Site Infection (SSI)
	32	Pathogen-Specific Healthcare-Associated Infection
	33	Wound Infection
	34	Postoperative Infection
	35	Hand Hygiene Compliance
	36	Alcohol-Based Hand rub Consumption (ABHR Consumption)
	37	Infection due to Pharmaceutical Care
	38	Iatrogenic Pneumothorax
	39	Neonatal Sepsis
Indicators related to prescription and medication errors	40	Wrong blood type
	41	Transfusion Reaction
	42	Medication Errors
	43	Adverse Drug Event (ADE)
	44	Potentially Inappropriate Prescribing (PIP)
	45	Adverse Effects of Antipsychotic Medications
Fall Indicator	46	Patient Falls
Patient Safety Friendly Hospitals Indicators	47	Percentage of implementation of Patient Safety Friendly Hospital (PSFHI) standards
	48	Average training hours of staff in the areas of patient safety and risk management
	49	Percentage of error management committee meetings held
	50	Percentage of implementation of error management committee resolutions
	51	Pressure Ulcer
	52	Intentional Self-Harm
	53	Failure to Rescue (FTR)
	54	Technical difficulty with procedure
Other special indicators	55	Diagnostic Error
	56	Unplanned Readmission
	57	Unplanned ICU Readmission
	58	Cautery burn
	59	Adherence to Laser Therapy Guidelines
	60	Patient Elopement/Patient Abduction
	61	Patient Misidentification
	62	Discharge of Infant to the Wrong Family

cess. Each worksheet represented a specific indicator group and included common fields such as month and indicator category. A hierarchical data structure was adopted to enable multidimensional analysis of the indicators.

The process concluded with the import of stored data into the QlikView platform. The visual features of the patient safety dashboard are presented in Table 3.

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Table 3. Visual and Functional Features of Patient Safety Dashboard

Visual features	Charts	Bar Charts	Comparison of contributing factors to incident occurrence (e.g., source of error in ADEs: physician, nurse, pharmacy, patient and others)
		Pie Chart	Comparison of the frequency of contributing factors, such as gender, associated with specific patient
		Gauge Charts	To display the performance of an indicator against a target or scale in first layer
		Line Charts	Visualization of time trends (e.g., postoperative respiratory failure across months of the year)
	Traffic light color coding	A traffic light color-coding scheme comprising green, yellow, and red was utilized to generate visual alerts. Green indicates compliance with expected standards, yellow signals a warning, and red denotes deviation beyond the defined threshold.	
	Layout	Design and arrangement of visual components, charts, tables, and text	
Functional Features	Trend analysis	Line charts were used to visualize trends over time, with the horizontal axis representing time (e.g., 12 months) and the vertical axis showing the number of occurrences. This format effectively illustrates sequential patterns in the data	
	Alerting	Color-coded visualization was used to signal alerts and identify the status of each key indicator. This approach facilitates rapid recognition of indicator status. Gauge charts were employed, utilizing three colors—green, yellow, and red—to represent compliance, warning, and threshold breach, respectively	
	Drill-down	The drill-down functionality of the dashboard enables access to deeper layers of data and detailed insights for each key performance indicator. This feature supports the identification of root causes and a comprehensive examination of contributing dimensions. It relies on a hierarchical data structure within the database, enabling seamless navigation from high-level indicators to the most specific influencing factors.	
	Flexibility in data presentation formats	The format in which information is presented in dashboards is shaped by a range of factors, including users' roles, cognitive and personality characteristics, analytical skills, and the complexity of the decision-making environment. To enhance dashboard effectiveness, it is essential to allow users to choose the preferred format of data presentation—such as various chart types or tables—based on their specific needs and contextual requirements.	
	Dashboard interactivity	Dashboard interactivity refers to the ability to modify visual elements such as layout, color schemes, and text formatting of tables and headings based on users' preferences and priorities. This feature enables users to personalize the dashboard interface, thereby improving usability and user satisfaction.	
	Filtering	To refine and narrow down the data displayed on a dashboard, enabling users to focus on specific subsets or dimensions of information that are most relevant to their analysis or decision-making	

In the third stage of the study, the dashboard was evaluated using a checklist, yielding the following results: compliance rate with design requirements, 77.77%; display features, 71.42%; alerting functions, 75%; analytical capabilities, 100%; layout structure, 100%; architecture, 100%; key performance indicator requirements, 75%; interactivity, 62.5%; and information presentation, 66.66%. The highest compliance rate was observed in architecture, layout, and analytical functionalities (100%), while interactivity showed the lowest compliance (62.5%). The overall compliance rate was 80.92%. Additionally, the dashboard's usability was evaluated using the SUS (Figure 1), which consists of 10 items rated on a 5-point Likert scale. Positive items (1, 3, 5, 7, 9) and negative items (2, 4, 6, 8, 10) were scored following the standard SUS methodology. Each respondent's total score was calculated and multiplied by 2.5 to yield a score out of 100. Based on responses from 10 participants, the average SUS score was 82.99.

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AVG.	Participant ID J	I	H	G	F	E	D	C	B	A	SUS Statement	Item Number
4.5	5	4	4	5	4	5	4	5	4	5	I think that I would like to use this system frequently.	1
1.5	2	2	2	1	2	1	1	1	1	2	I found the system unnecessarily complex.	2
4.5	5	3	5	5	5	5	3	5	4	5	I thought the system was easy to use.	3
1.3	1	1	1	2	2	2	1	1	1	1	I think that I would need the support of a technical person to be able to use this system.	4
4.6	5	3	5	5	4	5	4	5	5	5	I found the various functions in this system were well integrated	5
1.3	1	1	1	1	2	2	1	2	1	1	I thought there was too much inconsistency in this system	6
4.7	5	4	5	5	5	5	4	5	4	5	I would imagine that most people would learn to use this system very quickly	7
1.6	1	2	2	2	2	1	2	2	1	1	I found the system very cumbersome to use	8
4.6	5	4	5	5	5	5	3	5	4	5	I felt very confident using the system	9
1.5	2	2	2	1	2	1	1	1	1	2	I needed to learn a lot of things before I could get going with this system	10

x	20	13	19	20	18	20	13	20	16	20
y	18	17	17	18	15	18	19	18	20	18
sus Score	95	75	90	95	83	95	80	95	90	95

Figure 1. Individual Responses and Scores of Participants on the System Usability Scale
this table presents the individual item responses of 10 participants (A to J) on the 10 SUS statements, rated on a 1 to 5 Likert scale. The bottom section includes the calculated total SUS scores for each participant, which were derived based on the standard SUS scoring method.

Discussion

Ensuring patient safety and enhancing the quality of care have become central priorities in healthcare delivery to reduce errors and optimize clinical outcomes (22). Accordingly, this study was undertaken to identify and select patient safety indicators to design, develop, and evaluate a dashboard for enabling systematic monitoring, comprehensive tracking, and drill-down analysis of patient safety indicators—conceptualized as key performance indicators—as well as their related contributing factors, with the overarching goal of supporting the reduction of safety-related incidents in clinical settings.

As the most valuable components of dashboards, KPIs form the foundation for performance measurement. When appropriately selected, they help identify where corrective actions should be taken. Therefore, the primary considerations regarding KPIs focus on proper selection and development (23). All KPIs should align with the organization's goals (24) and be mapped to specific strategic objectives to enable dashboards to measure, monitor, and analyze progress effectively (23). While the study of Sheikhtaheri (10) employed the Delphi method to develop patient safety indicators, providing valuable groundwork in this area; however, it did not offer a structured categorization of the indicators. Building upon that foundation, the present study introduces a broader and systematically classified set of indicators that are consistent with international standards tailored to national needs. Furthermore, this study incorporates indicators related to 'Patient Safety Friendly Hospitals' for the first time, reflecting a key initiative by the Ministry of Health and Medical Education (MOHME). The MOHME piloted the Patient Safety Friendly Hospital Initiative in 2010 in a limited number of hospitals, aligning its efforts with the World Health Organization plans (12).

In dashboard design, functional requirements define the capabilities of the dashboards, including reporting, functionality updates, customization, reminders, performance indicator evaluation, real-time alerts and notifications, tracking, drill-down capabilities, and scenario analysis. Moreover, enhanced reporting features such as expand/collapse groups, interactive data sorting, bookmarking, and parameterization of interactive dashboard elements enable users to manipulate the appearance of reports during runtime (23, 25, 26).

The purpose of the dashboard is a primary determinant of its functional features. For example, when the dashboard is utilized as a monitoring tool, real-time alerts are essential, whereas scenario analysis is a crucial feature when it is used as a planning tool (23). Nonfunctional requirements encompass speed, security, ease of use, compatibility with various devices (such as PCs and laptops), integration with other systems, web-based design, inclusion of data warehouses, up-to-date data, and the use of data visualization elements based on user needs. These features enhance the adaptability and success of dashboards (25).

Effective visual design delivers critical information to the user, whereas poor visual design can lead to confusion and hinder decision-making. Therefore, achieving a balance between visual complexity and the usability of information is crucial (23). Studies have shown that highly accepted features include bar charts, tables, icons, images, and color coding for organizing and presenting data, as well as interactive elements such as radio buttons, collapsible panels, and expandable data sections (26). Furthermore, dashboards should offer a level of flexibility, enabling users to modify display templates. Theory-based guidance, such as pop-up windows and alerts, can assist users in selecting the most appropriate presentation format (27). As previously stated, the patient safety dashboard incorporates satisfactory visual and functional features.

Since the development and maintenance of data-intensive business intelligence tools, such as dashboards, can be time-consuming and resource-intensive, it is essential that these tools not only function effectively but also

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lead to measurable improvements. Ongoing evaluation of the dashboard's functionality during development, implementation, and post-launch is crucial for identifying obstacles to its application at both user and system levels, as well as uncovering potential issues that may not become evident until the dashboard is used over an extended period (28). A recent usability study by Malkani et al (2024) (29) detected 15 key design attributes for effective healthcare dashboards. This study found that these features improve usability and increase user trust. Likewise, the patient safety dashboard developed in this study incorporates most of these visual and functional elements in accordance with best practices.

Healthcare is increasingly driven by data and technology, revealing the importance of the selection of appropriate evaluation criteria and the use of effective dashboards in such environments (30). Given the lack of cohesive and comprehensive approaches for evaluating dashboards, a set of key criteria can be applied across various types. According to studies, these criteria include user customization, knowledge discovery, security, information delivery, alerts, visual design, system integration, and connectivity. Furthermore, several metrics have been proposed for evaluating dashboards, including usability, performance, learning, task suitability, situational awareness improvement, satisfaction, user interface, content, and system capabilities (30-32). Zhuang et al (32) proposed 3 general scenarios to assess the effectiveness of healthcare dashboards: user interaction, user experience, and system efficiency. In the present study, the evaluation method of Dyczkowski's study was conducted, and the requirements for design, display, alerting, analysis, layout, architecture, KPIs, interactivity, and information presentation were evaluated (9) .

Moreover, consistent with prior studies, usability was assessed using the SUS. For instance, Dowding et al. (2022) (33) reported a SUS score of 73.2 in evaluating a dashboard for home care nurses, while Østervang et al. (2024) (34) Reported a higher score (83.6) in the evaluation of a health information system in the emergency department. Other studies have similarly employed the SUS to assess healthcare dashboards (35-40) In the present study, the patient safety dashboard achieved a SUS score of 82.99, indicating a high level of usability (Figure 1).

The following considerations should be taken into account when developing patient safety dashboards as tools for enhancing quality and safety in healthcare:

1. User-Centered Content Delivery

Dashboards must deliver content that aligns with the specific needs and expectations of their users (6). They should be designed based on user-defined objectives and structured in a way that ensures that the content can be easily interpreted by various user groups, consistently meeting their expectations (6). End-user experience is a central attribute of dashboard software (30), offering a range of customization features empowering users to tailor the content according to their requirements (6). Data should be presented in a timely, complete, and accurate manner, ensuring that it is perceived as valid and trustworthy by users (6). Furthermore, dashboards should assist users in understanding the context of the data, the reasons for data collection, and the way it can be interpreted and utilized effectively (41).

2. Effective Data Visualization

Data visualizations should be designed to minimize cognitive load, ensuring that the intended message is easily and intuitively understood. Visual elements must be logically organized, offering users the flexibility to adjust the level of data granularity based on their informational needs (41). The use of high-contrast colors is essential, and dashboards should not rely solely on color to convey meaning, especially when accommodating users with color vision deficiencies. Instead, standardized color codes (e.g., red to signify danger) should be applied consistently (42). Incorporating a variety of visual formats, such as charts alongside tables, combined with clear, concise labeling and explanatory text, enhances both interpretability and user engagement (42). Consistent with these principles, the dashboard developed in the present study employed traffic light color coding (green, yellow, red) to support rapid interpretation, similar to the approach used in the study of Dowding et al. (2022) (33) as well as other healthcare dashboards designed for monitoring hospital-acquired conditions, where quick visual alerts are critical for timely intervention (43, 44).

3. Data Utilization

The ability to track data over time and leverage historical information for future decision-making is a critical feature of effective dashboards. Incorporating storytelling techniques when presenting data plays a vital role in fostering user engagement and enhancing comprehension (42). Data consistency within healthcare dashboards is essential to ensure the accuracy and reliability of the information that is presented (42). Moreover, the integration of predictive analytics powered by artificial intelligence enables the generation of more accurate forecasts, thereby supporting healthcare professionals in making more informed clinical decisions. Effective dashboard design must integrate principles of health informatics and human factors to safeguard the efficient and accurate communication of information (5). Striking an optimal balance between technical sophistication, user-friendliness, and alignment with real-world requirements is essential for developing dashboards that are both functional and impactful in healthcare settings.

A limitation of this study was related to the accessibility and quality of the data. In certain instances, the available data required cleaning and preprocessing to ensure suitability for analysis and dashboard development. Furthermore, access to patient safety data was constrained due to confidentiality concerns. This challenge was mitigated by obtaining formal confidentiality agreements from the research team to ensure the ethical application and protection of sensitive information.

Conclusion

This study developed a design protocol for patient safe-

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ty dashboards through stakeholder involvement based on KPIs, followed by evaluation using two distinct approaches. A preliminary model of a patient safety dashboard was ultimately proposed. Patient safety is a domain in which well-designed dashboards can have a significant impact by alerting decision-makers to potential issues, thereby contributing to the prevention of harm (45). Timely reporting, follow-up, and continuous monitoring of incidents contribute to improving care quality and reducing damage to individuals, communities, and healthcare organizations. Therefore, implementing a patient safety dashboard in hospitals could serve as a valuable tool for monitoring safety incidents, conducting root cause analyses, comparing event trends over time, and eventually working to eliminate known contributing factors. This, in turn, can enhance the quality of care and improve patient safety outcomes in hospital settings. It is essential to recognize that dashboard development is an ongoing process, as organizations ideally exist in a constant state of learning and evolution. Consequently, it is essential to regularly review and update current business goals, assumptions, strategies, and measurement targets to ensure alignment with the organization's dynamic needs.

Authors' Contributions

Conception, Design: Reza Safdari, Mahni Mehdibagli, Mahboobeh Mirzaee.

Search and data collection: Mahni Mehdibagli.

Writing and revision: Mahni Mehdibagli, Mahboobeh Mirzaee

All authors have read and approved the final version of the manuscript.

Ethical Considerations

This study was approved by the Ethics Committee of Tehran University of Medical Sciences (Ethics code: IR.TUMS.SPH.REC.1395.1974).

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Conflict of Interests

The authors declare that they have no competing interests.

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