4-1-2024

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Informatics in Medicine Unlocked 47 (2024) 101489

Contents lists available at ScienceDirect

Informatics in Medicine Unlocked

journal homepage: www.elsevier.com/locate/imu

The design of a quality improvement dashboard for monitoring spinal cord and column injuries

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ARTICLE INFO

Keywords:
Indicators and reagents
Quality of health care
Spinal cord injuries
Disease registries
Dashboard

ABSTRACT

Background: Interactive dashboards are a powerful tool for dynamic visualization and monitoring of patient performance and serve as a useful to for optimal decision-making. The National Spinal Column and Cord Injury Registry of Iran (NSCIR-IR) was designed to efficiently display and broadcast important patient care data. This has been achieved through an electronic dashboard display (graph and visual displays), rather than traditional static paper reports (text).
Objectives: The objective of this study was to design and develop an electronic visual dashboard as a display system to monitor the quality of care in the NSCIR-IR collaborating centers.
Methods: The indicators chosen were 20 pre-hospital and in-hospital quality of care (QoC) assessment tool indicators. A structured query was created from the NSCIR-IR system database to create the dashboard database. The Microsoft Power BI software was used. After data cleaning, filtering of erroneous records, and modeling, visual displays were designed and evaluated.
Results: The dashboard reported on quality of care (QoC) for 2,745 patients registered in NSCIR-IR. 17% of registered cases had at least one data error in the quality of care indicators. These errors were automatically filtered by the system. The two most prominent weaknesses in (QoC indicators were delay in patient transfer by EMS (Mean and SD were 9.54 ± 13.8 h) and timing of surgical spinal cord decompression (114.5 ± 45.3 h).
Conclusions: Electronic dashboards provide efficient and concise data summaries “at a glance”. However, their value and accuracy are dependent on the entered data quality. Identifying data source errors and correcting them continuously led to improved quality of data.

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https://doi.org/10.1016/j.imu.2024.101489
Received 13 August 2023; Received in revised form 30 March 2024; Accepted 30 March 2024
Available online 1 April 2024
2352-9148/

1. Introduction

Over the last decade there has been considerable improvement in the quality and quantity of patient information particularly due to improved electronic records. Information technology has greatly advanced the ability to access and analyze this data. Business intelligence tools have enabled comprehensive data organization and visualization or display. Information dashboards or electronic billboards have become an essential tool for managers and decision-makers in numerous fields particularly outside of healthcare. However, in healthcare there is a greater need for immediate, accurate, real-time electronic reporting. Presently, there is a need for improved health system's performance in disease prevention and to enhance the quality of care, reduce costs, and increase productivity [1–5].

In general, performance evaluations and status reports are classified into two main categories: static and dynamic reports. These reports can be further subcategorized as cross-sectional or real-time reports. Traditional routine health performance reports are difficult to access, compare, and make decisions. Business intelligence is a broad set of technologies, applications, and processes that collect, store, and analyze data from internal and external sources to integrate information, identify patterns, and make informed decisions. Business intelligence (BI) tools, especially information dashboards enable the creation of real-time, dynamic, and interactive visual displays or reports that enhance decision-making. Electronic dashboards are the most powerful BI tools for a dynamic display of large amounts of data such to monitor processes and aid in decision-making [6]. In general, electronic dashboards have the following advantages [7]:

- Immediate visualization of performance indicators,
- Quick differentiation of positive, unchanged or negative trends,
- Save time in the production and preparation of reports,
- Provide the instantaneous ability to change performance goals.

These dashboards provide a greater ability for analysis (so-called drill-down) into details, root cause analysis, and even based on "what ifs" scenarios [8–10]. Dashboards are based on the principles of visual display and perception, since visualization of images results in efficient and effective processing, it is possible to comprehend the maximal amount of information in the minimum time [11].

There is a plethora of precise data on the traumatic spinal column and cord injury in Iran that has been collected through the National Spinal Column/Cord Injury Registry of Iran (NSCIR-IR) [12]. Organizing this data such that it is displayed in a dynamic and real-time way, improves communication and results in performance improvement actions. Thus monitoring, recording and tracking data improves quality performance by allowing adjustment and improvement in patient care. However, the effectiveness of dashboards requires the creation of a balanced set of performance or quality improvement indicators. Therefore, the selection, classification, and definition of indicators are very important [13]. Accordingly, for each indicator placed in the dashboard, the numerator, denominator, purpose, formula, type, target population, data sources, cut-off point, standard, or norm should be defined [14].

In this review, the quality-of-care indicators were summarized for spinal trauma patients and valued through the Delphi method [15,16]. Now in the present study, we implement these indicators with BI tools as a monitoring system to monitor the quality of care in the 9 hospitals collaborating with NSCIR-IR.

2. Material and methods

2.1. Indicators

Eighty-seven qualities of care indicators were identified by the previously published review performed by our research group in 2019 [15]. In another study, again through an expert panel, 27 indicators with acceptable content validity (CVI) and content validity ratio (CVR) were chosen as quality of care assessment for TSCI [16]. Twenty of these 27 indicators were select and routinely collected and entered in the NSCIR-IR. Seven additional indicators related to post-hospital quality which can only be collected through the post-discharge interview were excluded. These indicators are classified into pre-hospital and hospital categories. A data dictionary was prepared for each indicator as detailed in Table 1.

2.2. Data source

Data were extracted from the NSCIR-IR database. They were the variables needed to calculate the selected indicators. In the first stage before dashboard design, these compulsory variables were determined by the technical development team, and based on the indicators profile (Table 1). They included the following variables: Hospital name, record status, Birth date, gender, injury date and time, injury province and city, injury cause, mode of transport in prehospital, arrival time to the first health facility, triage time, inpatient admission date and time to spinal care facility, surgery intervention, decompression data and time, spinal cord injury status and type, ASIA Impairment Scale, hospital complications, ICU LOS, discharge date and time, discharge status.

2.3. BI database

Utilizing the identified variables, the data table schema was developed to create the BI database. This database served to extract selected data from the main database during transform, and loading (ETL) process of data from the SQL database of the NSCIR-IR. The connection between the database and the BI tool (which was the Microsoft Power BI software, version 2.9, 2021) including SQL server authentication via server name and password was established by the technical team.

To increase data extraction time from the NSCIR-IR database into the query such that there was rapid updating of the data, a separate server was utilized. Therefore, real-time updates were performed without interruption. Therefore, any changes in the data (due to the addition of new patients registered in the registry system) were immediately reported and displayed.

2.4. Data cleaning and transforming

As shown in Fig. 1, after establishing the database and BI tool connection, data cleaning, transformation, and creation of metrics was performed by a medical informatics specialist familiar with the NSCIR-IR data as follows:

i. Controlling and manually determining the exact type of data in the prepared query that reads data from the registry database and automatically displays.
ii. Defining and implementing programming instructions for converting variables and data from Farsi into the English language. (English is text for Power BI).
iii. Detecting data errors, including missing data, out-of-range data, and conflicts between each of the variables, and defining instructions for automatically clearing them. In time of creating measures and writing the formulas in DAX language, instructions were written in which those cases with negative, unacceptable, or blank values are filtered and the indicator calculation is done without considering those cases. By checking the number of cases imported to the BI database and the number of filtered cases for the report view, the number of erroneous cases could be identified.

2.5. Implementation of indicators and dashboard design

It was necessary to create some computational variables from raw

Table 1
The characteristics of the selected indicators for the monitoring system.

Level	Type	ID	Name	Definition	Formula	Related Indicators	Data Sources in NSCIR-IR	Display mode
Pre-hospital	Process	PPC-01	Cervical spine immobilization	Rate of patients who received cervical spine immobilization (collars) from EMS	$\frac{Number\ of\ EMS\ immobilized\ patients\ with\ collar}{Sum\ of\ EMS\ transfered\ patients} * 100$	AF[a] by EMS Transfer Rate	Admission form,	Line Chart, Horizontal/Vertical Bar/Column Bar
		PPC-02	Spinal immobilization by Backboard	Rate of patients who received spinal immobilization by backboard from EMS	$\frac{NumberofEMS\ patients\ with\ spine\ immobilized}{Sum\ of\ EMS\ transfered\ patients} * 100$	AF[a] by EMS Transfer Rate	Admission form	Line Chart, Horizontal/Vertical Bar/Column Bar
		PPC-03	Average time from injury to arrival at the first facility	The average time interval between the incident and arrival at a first medical facility in EMS transfers	$\frac{Sum(Arival\ time\ to\ the\ first\ facility - injury\ time)}{Sum\ of\ EMS\ transfered\ patients}$	EF[b] for OPC-02	Admission form	Box Plot/Cards: Single
	Outcome	OPC-01	Rate of timely delivery to the first medical center	Rate of patients transferred by ambulance who were delivered to the first center in less than an hour	$\frac{Total\ ofEMS\ patients\ delivered\ to\ the\ first\ center\ in < 1hr}{Sum\ of\ EMS\ transfered\ patients} * 100$	AF by PPC-03	Admission form	Gauge
		OPC-02	Average time from Injury to arrival at a specialized center	The average time interval between the incident and arrival at the final/specialized medical facility	$\frac{Sum(time\ of\ triage\ admission\ in\ the\ final\ facility - injury\ time)}{Total\ of\ patients}$ $\pm$ SD	AF by PPC-03	Admission form	Box Plot/Vertical Bar
		OPC-03	Rate of timely arrival to the specialized medical center	The rate of patients transferred to the final center in less than an 8-h	$\frac{Total\ of\ patient\ transferred\ to\ the\ final\ center\ in < 8hr}{Total\ of\ patients} * 100$	AF by PPC-03 & OPC-02	Admission form	Gauge
Hospital	Process	PHC-01	Average time from injury to decompression	The average time interval between the incident and decompression surgery	$\frac{Sum(time\ of\ decompresion - injury\ time)}{Total\ of\ patients\ under\ surgery}$ $\pm$ SD	AF by OPC-02 Effective for PHC-02,03,04	Admission form & intervention form	Box Plot
		PHC-02	Rate of Early decompression ($\leq$ 24hr)	Rate of patients who undergo surgery in less than 24 h of injury	$\frac{total\ ofpatient\ who\ undergo\ surgey \leq 24hr}{Total\ ofpatients\ who\ undergo\ surgey} * 100$	AF by OPC-03 & PHC-01	Admission form & intervention form	Stacked Bar Chart
		PHC-03	Rate of early decompression (<48 h)	Rate of patients who were under decompression surgery in >24 h and <48 h after injury	$\frac{total\ number\ ofpatient\ with\ surgey > 24hr\ but < 48hr}{Total\ number\ of\ patients\ who\ undergo\ surgey} * 100$	AF by OPC-03 & PHC-01	Admission form & intervention form	Stacked Bar Chart
		PHC-04	Rate of late decompression >48 h	Rate of patients who were under decompression surgery in >48 h after of injury	$\frac{total\ number\ ofpatient\ with\ surgey > 48hr}{Total\ number\ of\ patients\ who\ undergo\ surgey} * 100$	AF by OPC-03 & PHC-01	Admission form & intervention form	Stacked Bar Chart
		PHC-05	Average ICU length of stay (ICU LOS)	The average length of stay in ICU in patients with traumatic spinal column and cord injury	$\frac{Sum\ of\ ICU\ LOS\ in\ patient\ with\ at\ least\ one\ day\ of\ ICUU}{Total\ number\ of\ patients\ who\ stayed\ in\ ICU}$ $\pm SD$	-	Discharge form	Box Plot/Cards: Single
		PHC-06	Average of ICU length of stay (ICU LOS) in patients with SCI separately in AIS	The average length of stay in ICU in patients with traumatic spinal cord injury	$\frac{sum\ ofICU\ LOS\ in\ SCI\ patients(AIS)who\ stayed\ least\ one\ day\ in\ ICU}{Total\ number\ of\ SCI\ patients\ who\ stayed\ in\ ICU}$ $\pm SD$ *A or B or C or D	-	Injury from & Discharge form	Vertical Bar/ Column Bar
		PHC-07	Total Hospitla LOS (Acute LOS)	The average length of stay in the hospital	$\frac{Sum\ of\ LOS\ (days)}{Total\ number\ of\ patients}$ $\pm$ SD and IQR	–	Admission form & discharge form	Box Plot/Cards: Single
		PHC-08	Total hospital LOS (Acute LOS) in patients with SCI separately in AIS	The average length of stay in hospital in patients with traumatic Spinal cord injury	$\frac{Sum\ of\ \text{LOS in SCI patient}\ (AIS)*}{Total\ SCI\ patients*}$ *A or B or C or D	–	Injury form, Admission form & discharge form	Vertical Bar/ Column Bar

(*continued on next page*)

Table 1 (*continued*)

Level	Type	ID	Name	Definition	Formula	Related Indicators	Data Sources in NSCIR-IR	Display mode
	Outcome	OHC-01	The hospital mortality rate in traumatic Spinal column and cord injury	Rate of mortality in hospital in patients with traumatic Spinal column and cord injury	$\frac{\textit{Number of patients who died in hospital}}{\textit{Total number of patients}} * 100$	–	Discharge form	Gauge chart
		OHC-02	The hospital mortality rate in patients with SCI	Rate of mortality in hospital in patients with SCI	$\frac{\textit{Number of SCI patients who died in hospital}}{\textit{Total of SCI patients}} * 100$	–	Injury form and Discharge form	Gauge chart
		OHC-03	Surgery site infection	Rate of patients with surgical site infection	$\frac{\text{Total number of SSI}}{\textit{Total number of surgey}} * 100$	–	Complication's form	Line Char, Horizontal/Vertical Bar/Column Bar
		OHC-04	Pressure ulcer rate in acute care	Rate of patients with bed sores in the hospital	$\frac{\textit{number of patient with pressure ulcer}}{\textit{Total number of patients}} * 100$	–	Pressure ulcer form	Line Chart, Horizontal/Vertical Bar/Column Bar
		OHC-05	Pressure ulcer rate in SCI patients with AIS A&B	The rate of patients with bed sores in the hospital for SCI patients with AIS A&B	$\frac{\textit{number of SCI patient(AIS A\&B) with pressure ulcer}}{\textit{Total number of SCI patients with AIS A\&B}} * 100$	–	Pressure ulcer form	Line Chart, Horizontal/Vertical Bar/Column Bar
		OHC-06	Urinary tract infection (UTI) rate	Rate of patients with UTI in the hospital	$\frac{\textit{number of patient with UTI}}{\textit{Total number of patients}} * 100$	–	Complication's form	Line Chart, Horizontal/Vertical Bar/Column Bar

a: Affected by.
b: Effected for.

variables. We created them with the "M" formalization language and wrote instructions to perform the calculation automatically on each update. These computational variables included the following, time interval between injury and …, in hours:

i. Arrival at First medical center.
ii. Arrival at Specialized center
iii. Surgical decompression.
iv. The time interval between the time of admission and the time of discharge, by day.
v. Duration of stay in the ICU.

In the next step, the process of creating metrics and defining them in the "DAX" formulation language was performed in the software reporting environment, which generally included the following steps:

1. Creating the basic indicators (such as count) as in the following example:

count.limb immobilization = COUNTX(filter(DossierDataForBI, [Immobilization] = "Limb Immobilization" && DossierDataForBI[TransferMode] = "EMS"),DossierDataForBI[PatientId])

2. Creating the secondary indicators (such as rate, average, median, …) as in the following example:

Average.ICU.LOS = AVERAGEA(DossierDataForBI[ICULOS])

Then, visual objects were designed to display for each of the indicators. At this stage, based on the predefined categories, the indicators were separated. Some indicators needed to be examined at different time intervals. The drill-down capability was provided for them by their related date variable.

2.6. *Evaluation*

After designing the visual parameters and the required objects for display, based on the principles of dashboard design and aesthetic principles, the system was shown to three experts for evaluation. Two experts were specialized in neurosurgery and one had international experience with health metrics. This evaluation was performed in the technical development phase, not during the adoption phase. It was used to provide feedback to the design team for technical issues and verification. Therefore, it was a non-quantity evaluation with a focus on cognitive aspects of the interaction between the system and the audience/stakeholder. The evaluation was performed from the following aspects:

i. Confirming the proper graphs selected for each indicator based on the type of indicator and the purpose of display
ii. The appropriateness of graphs, layout, and statistics chosen
iii. To identify areas for improvement in understanding the defined care performance metrics

3. Results

Twenty indicators were selected according to data availability in NSCIR-IR. They were used for quality of care assessment of pre-hospital and hospital care services. The characteristics of the selected indicators are detailed in Table 1. A profile was written separately for each indicator which contained the following information: indicator ID, name, definition, type of indicator, level/category, formula, numerator definition, and its data source, denominator definition and its data source, reporting frequency, mode of data collection, ID of related indicators (effective or affected indicator), the indicator display mode and if the display mode was gauge, the target, acceptable and unacceptable ranges of that indicator (including the bad; warning and good intervals), notes/comment and references.

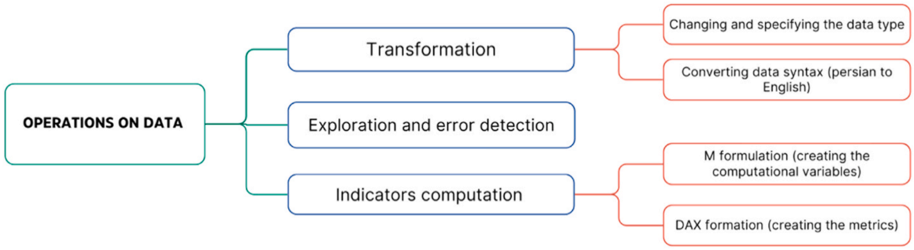

Fig. 1. Operations on data for dashboard design.

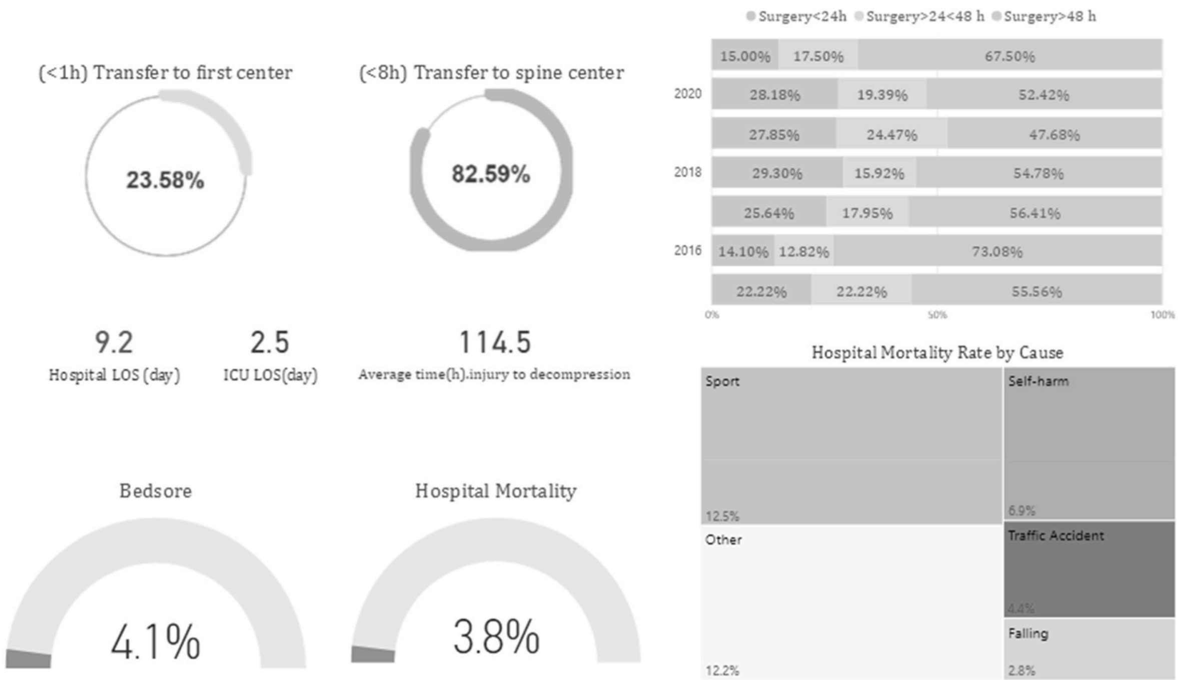

Fig. 2. High-level view of key performance indicators.

Many registered cases (greater than 600 out of 3,350) were automatically filtered when calculating and displaying metrics. As described in the methods, after the data was loaded and data exploration process, instructions were implemented to automatically clean up missing, out-of-range, and inconsistent values for each variable.

Basic and secondary indicators were created and displayed with the appropriate graphs, charts, and metrics in the reporting system.

According to the category of indicators in terms of the level of care (i.e., pre-hospital and hospital setting) and also the logical sequence of information that could be represented, four displays for the monitoring system were presented. (i) general view to provide general statistics of approved cases and their distribution; (ii) a high-level view that shows key performance indicators from each of the pre-hospital and hospital sections (Fig. 2); (iii) pre-hospital view (Fig. 3) (iv) and finally, hospital view (Fig. 4). The monthly, quarterly, and annual trends in indicators at each hospital can be observed and monitored. Filters designed to refine the visuals based on hospital names, spinal cord injury patients, and non-SCI patients to compare. During three separate sessions with three experts, selected displays of some indicators whose distribution was not normal were changed.

Based on the dashboard monitoring system that is designed, we can see the status of quality-of-care indicators provided to 2,745 traumatic spinal column/cord injury patients during six years of registration in NSCIR-IR. Although this number was less than the actual number of patients registered in the NSCIR-IR, as mentioned earlier, these were cases where all the variables affecting the indicators were error-free and accurate.

A general overview of the dashboard monitoring system notes 2,745 NSCIR-IR patients where 23.6% were transferred to the initial medical center in less than 1 h from the injury event and 82.6% were transferred to a specialized spine center in less than 8 h. The status of other indicators was as described in Table 2. The dashboard illustrated an improvement in early surgical decompression over time since 2015 which is an important metric in that studies have shown early surgery can lead to improve neurologic recovery.

4. Discussion

Data scientists have shown that visual data is perceived and interpreted faster than textual data by several magnitudes [17]. Dashboards are visual displays of data that are powerful tools. They enable health stakeholders, from medical teams to managers and policymakers, to quickly assess performance status by standards or from various perspectives, identify strengths and weaknesses, and make quick critical decisions based on information to improve performance [18,19].

Previously, healthcare dashboards were predominantly utilized by hospital management to monitor patients waiting times, admission to discharge time, emergency bed occupancy rate, and delay emergency diagnostic procedures [20–24]. Presently, numerous studies have illustrated the benefits of dashboard's usage for patient safety and quality of

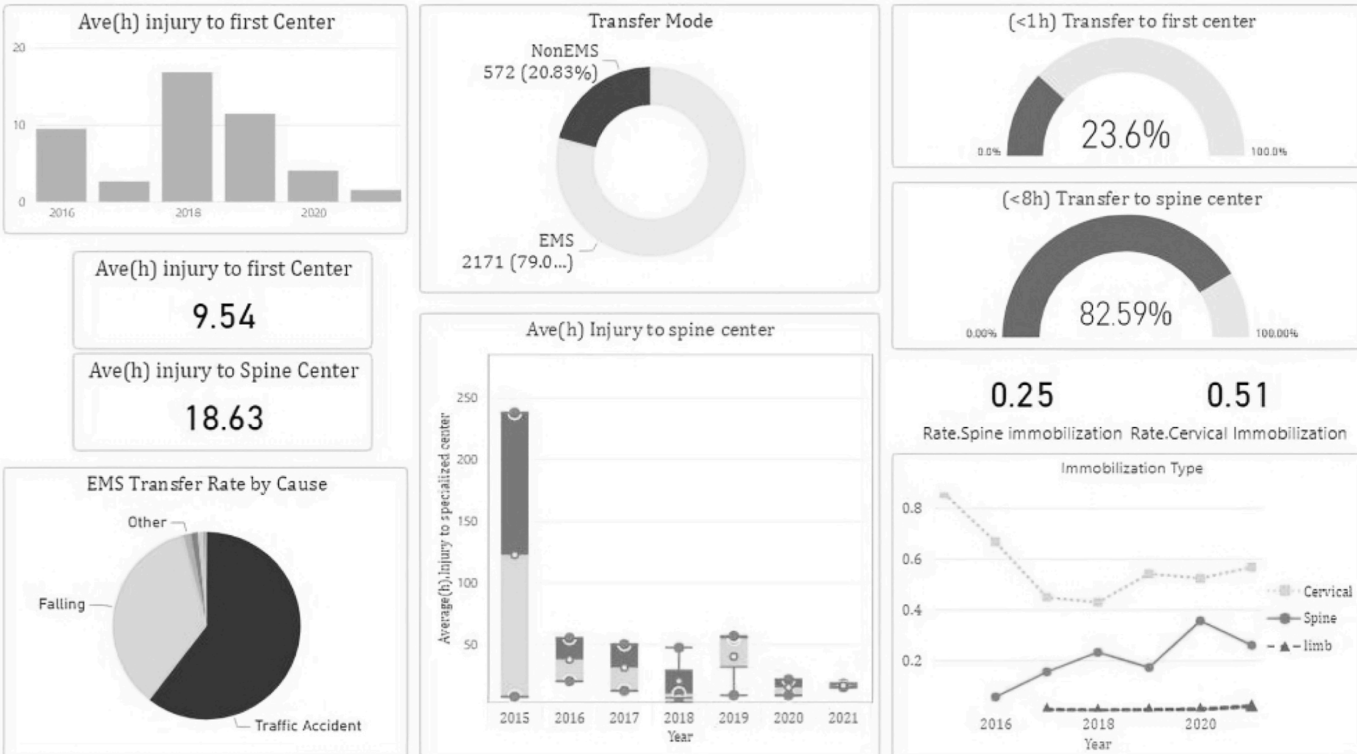

Fig. 3. Screen capture of indicators related to pre-hospital in the monitoring system.

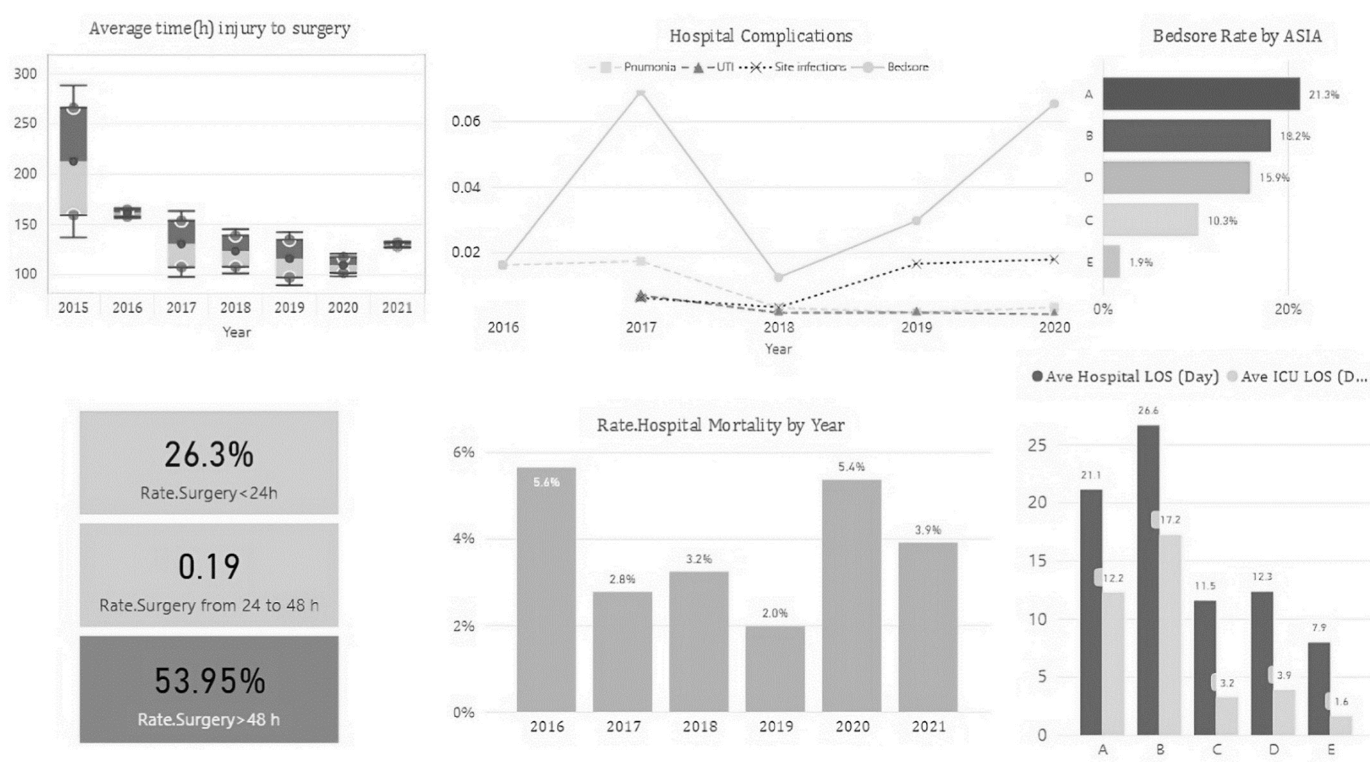

Fig. 4. Screen capture of indicators related to the hospital in the monitoring system.

care indicators in numerous healthcare settings [17,25,26].

Laurent et al. developed and evaluated a dashboard for quality assessment of the anesthesia unit on compliance with patient care guidelines at Lille University Medical Center [27]. In another study Anand's et al. created a dashboard to monitor outcome metrics such as ventilator-acquired pneumonia, catheter-acquired UTI, bloodstream infections as well as bedsores, postponed surgeries, and length of stay in the pediatric cardiac ICU [28]. This dashboard was updated monthly and a detailed report sent to all stakeholders. In addition, it was available through the internet for real-time assessment.

Table 2
Overall situation of quality of care indicators in NSCIR-IR centers based on the designed monitoring system.

Indicator Name	Indicator value
Cervical spine immobilization (%)	51
Spinal immobilization by Backboard (%)	25
Average time from injury to arrival at the first facility (hour)in EMS transferred patients	9.54 ± 13.8
Rate of timely delivery to the first medical center (%)	23 0.58
Average time from injury to arrival to specialized center (hour) in EMS transferred patients	18.63 ± 21.6
Rate of timely arrival to the specialized medical center (%)	82.59
Average time from injury to decompression (hour)	114.5 ± 45.3
Rate of early decompression (≤ 24hr)	26.3
Rate of early decompression (24hr< & >48 h)	19.75
Rate of late decompression >48 h.	53.95
The mean of ICU LOS (days)	2.5 ± 3.8
Mean of ICU LOS in patients with SCI (days)	A = 12.2 ± 3.4 B = 17.2 ± 4.6 C = 3.2 ± 3.7 D = 3.9 ± 3.2 E = 1.6 ± 0.8
Average LOS (Acute LOS) (days)	9.2 ± 1.7
Mean LOS (Acute LOS) in patients with SCI (days)	A = 21.1 ± 7.3 B = 26.6 ± 6.1 C = 11.5 ± 4.9 D = 12.3 ± 4.5 E = 7.9 ± 3.2
The hospital mortality rate in the traumatic spinal column and cord injury (%)	3.8
The hospital mortality rate in patients with SCI (%)	14.7
Surgery site infection (%)	2.6
Pressure ulcer rate in acute care (%)	4.1
Pressure ulcer rate in SCI patients with AIS (%)	A = 21.3 B = 18.2 C = 10.3 D = 15.9 E = 1.9
Urinary tract infection (UTI) rate (%) in spine trauma	0.3

Gardner et al. reported on using benchmarks to improve reporting on patient falls through the Pennsylvania Patient Safety Reporting System. This dashboard was well received and used by 41.3 percent of Pennsylvania hospitals for fall prevention. The addition of this dashboard improved quality improvement assessment and reporting [29]. In another study, a monitoring dashboard for adverse events (ADEs) of opioid drugs was designed and developed on base of US Medicare & Medicaid Services (CMS) data [30]. That dashboard provided users trends in ADE incident rates by the hospital, patient groups, surgery type or subtype, and the impact of adverse events on the length of stay [30]. Some other dashboards use population-based epidemiological data to monitor the spread of the disease, such as the HIV in Kenya [31] and in the United States to investigate the incidence and prevalence of COVID-19 [32].

In order to display and communicate the quality of care for traumatic spine injured patients a dashboard was created. The data noted a 3.8% in-hospital mortality rate for trauma patients and 14.7% in spinal cord injury patients. In a study by Chhabra et al. mortality was 10% in patients with complete acute traumatic spinal cord injury (TSCI) [33]. In a study on elderly patients with SCI registered in Rick Hansen Spinal Cord Injury Registry (RHSCIR), in-hospital mortality was reported at 16% [34].

The incidence of pressure ulcers (PU) was 4.2 % in the whole of NSCIR-IR and a range of 21.3–1.9% in SCI patients. This was relatively similar to the pressure ulcer rate of the study's Brienza [35] and in developing countries [36]. Van Weert et al. reported PU in acute hospitalization at 32% [37]. Accordingly, the incidence of NSCIR-IR hospitals is relatively similar in terms of mortality and pressure ulcer rates, although further quality improvement processes are in progress.

As noted in the methods and results, the performance of pre-hospital and hospital services in the centers where the data was obtained currently has some areas of improvement, including delays in patient transfer to the first care facility in EMS transport and the limited use of immobilization devices for injured patients in ambulance transport. Another metric which shows need for improved communication is pre-hospital stabilization. Only 51% of NSCIR-IR patients were immobilized in a cervical collar for transfers. It was recommended for all patients with a potential spinal injury in pre-hospital transfer.

Another area of improvement was the timing from injury to spinal cord decompression. Studies have shown that earlier decompression particularly less than 24 h s improves neurologic outcomes [38–40]. In the study cohort,26% had decompression within 24 h, these results were similar to other developed countries where transportation logistics appear to be a significant barrier. Elderly traumatic SCI patients registered in RHSCIR from 18 acute and 12 rehabilitation facilities across Canada, results show from 826 patients who needed surgery, the rate of <24 h decompression was 28.7% [34]. Although a decreasing trend has been observed from 2015 to 2021, further statistical analysis is needed to confirm and examine the significance of these decreasing changes in NSCIR-IR hospitals. By record in data and monitoring the trends, it may be possible to measure the impact of dashboards use on performance [41]. Even if the increase in protocol adherence be related to the Hawthorne effect, it is desirable and better for the patients. The Hawthorne effect occurs when people improve their performances since they realize they are being observed or studied [42]. Gupta et al.,' study on TBI patient time from hospital arrival to treatment there was a significant improvement noted due to the Hawthorne effect [43].

A clinical dashboard can aid in monitoring performance and lead to quality improvements [19]. These dashboards provide valuable feedback in an instantaneous manner that is rapidly comprehended due to the visual display [10,44,45]. However, evaluating the true impact of dashboards on improving the quality of care is difficult. Murphy et al. in a systematic review noted the majority of the studies on dashboards were case reports without detailed analysis about the impact of these tools [25]. 'Several studies have shown that after a period of dashboard implementation, use, and feedback, there are reductions in medical errors, infections, adverse events, and patient improvements are observed [29,46].

The creation of dashboards improves communication and leads to changes in organizational culture, monitoring adherence to guidelines, and emphasizing the implementation of quality assurance and safety protocols along with the use of dashboards have been effective. Conway and colleagues [47] used the term "campaign," to describe all the actions and programs that result from setting up dashboards to reduce errors and improve quality of care. These effects include improvements in the culture, increase safety and quality, reporting and studying performance, discovering the causes, feedback and regular announcements. Dashboards were the integral part of this campaign that facilitates regular reporting and monitoring. Therefore, after the implementation of the dashboard, the NSCIR-IR should continue to foster and adapt the principles of quality of care through feedback.

In addition, despite automatic preventive mechanisms to prevent incorrect data from being entered into the NSCIR-IR system including direct human oversight on the recorded data by quality reviewers [48], 17% of the recorded cases were not considered in calculating the indicators due to errors in the data. Therefore, there is a great need to identify the source of errors and fix them while preventing the recurrence of errors or conflicts. We could have removed the automatic filters that detected errors and allowed more data to be used in the calculation and visualization of the indicator, but this would have made the interactive dashboard reports inaccurate. This was the main limitation of the study. Alhamadi et, al. Who interviewed 17 dashboard design professionals about their challenges and problems reported poor data quality as a major problem [49]. Koronios et al. emphasized that data source optimization from data quality dimensions is critical to develop a meaningful dashboard [50].

About the transferability of this system to other healthcare settings, it can be said that the tool used, which was Power BI Report Server, is compatible with a wide range of data sources, including spreadsheets, SQL or MySQL-based databases, data warehouses, and spreadsheets or data files. Therefore, with BI tools (e.g., Power BI, Tableau, and Qlik) the possibility of developing similar dashboards on any information system in healthcare has been facilitated. Developed dashboards for patient outcomes of anesthesia in British Columbia Children's Hospital [51], COVID-19 management in Mashhad [52]and in the United Arab Emirates [53], and staffing in a medical center in California [54] are examples of studies that used these tools.

5. Conclusions

This research illustrates the importance of recording and displaying quality improvement for healthcare settings and fields. The result is improvement of the quality of care on patient performance. By displaying data, the positive and negative results are quickly discovered, the trend of changes can be observed and monitored, and improved leading to better patient care.

Ethical statement

NSCIR-IR approved by Research Ethics Committees of School of Medicine for Tehran University of Medical Sciences with approval ID of IR. TUMS.MEDICINE.REC.1401.133.

Funding support

The study was supported by Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran (Grant number 41444-38-01- 98).

CRediT authorship contribution statement

Zahra Azadmanjir: Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mohsen Sadeghi-Naini:** Writing – review & editing, Validation, Methodology, Formal analysis. **Mohammad Dashtkoohi:** Writing – review & editing, Data curation. **Maziar Moradi-Lakeh:** Writing – review & editing, Visualization, Validation, Methodology. **Jalil Arabkheradmand:** Writing – review & editing, Validation. **James S. Harrop:** Writing – review & editing, Validation, Supervision. **Vafa Rahimi-Movaghar:** Writing – review & editing, Validation, Supervision, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The study was supported by Sina Trauma and Surgery Research Center (STSRC), Tehran University of Medical Sciences, Tehran, Iran (Grant number 41444-38-01- 98). In addition, we thank the Iranian Ministry of Health and Medical Education's Deputy for Research and Technology (Grant number 57404-1401-1-210) as well as STSRC (Grant number 62693-1401-3-93) for their support of the NSCIR-IR.

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