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Monitoring Guideline Adherence in Severe Traumatic Brain Injury

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Abstract. Traumatic brain injuries (TBI) significantly impact global health, often resulting in death or long-term disability. We developed a quality dashboard to monitor adherence to severe TBI guidelines, leveraging data from Rennes University Hospital's clinical data warehouse collected between January 2020 and December 2023. We included 193 patients from the surgical ICU who were over 18 years old and excluded those without adequate intracranial pressure (ICP) monitoring data. The study utilized the French Anesthesiology and Intensive Care Society guidelines and the Brain Trauma Foundation's 4th Guidelines Edition to assess guideline adherence over the first seven days of hospitalization. Our dashboard, built using the flexdashboard and Plotly R libraries, presents patient demographics, clinical assessments, and treatment adherence. Despite limitations, such as reduced interoperability and the absence of clinician usability testing, our tool represents a pioneering effort in TBI guideline compliance, with plans for future enhancements including expanded guideline evaluation and improved dashboard sharing capabilities.

Keywords. Traumatic brain injury, Intensive care, Clinical dashboard, Guidelines

1. Introduction

Every year, traumatic brain injuries (TBI) impact tens of millions of people globally, ranking as a leading cause of death and prolonged disability [1]. Patients with severe TBI, defined by a Glasgow Coma Scale score of less than 8 or presence of pupillary abnormalities at admission, require intensive care unit (ICU) management. Their care involves monitoring and therapeutic interventions aimed at controlling intracranial hypertension, which poses a significant threat to both vital and functional prognosis. The management of these patients is based on national and international guidelines [2, 3]. However, adherence to these guidelines is inconsistent [4]. Quality dashboards provide information on standardized performance metrics to assist with operational decision making. In healthcare, clinical dashboards offer feedback to professionals about

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the compliance to guidelines, thereby helping to improve practices [5]. The aim of this study was to create a quality dashboard that provides feedback to clinicians on adherence to TBI guidelines, to improve clinical practices and subsequently enhance patient outcomes.

2. Methods

Data were extracted from the Rennes University Hospital clinical data warehouse (CDW) [6] from January 1, 2020, to December 31, 2023. Inclusion criterion was admission to the surgical ICU for a severe traumatic brain injury. Exclusion criteria were absence of ICP monitoring or ICP monitoring during less than twenty minutes. The study focused on the first seven days of hospitalization, which is the time most at risk for intracranial hypertension. Guidelines were selected by two clinicians (LDJ, ALG) from the French Anesthesiology and Intensive Care Society guidelines [2] and Brain Trauma Foundation 4th Guidelines Edition [3]. To create our dashboard, we used the requirements for a quality dashboard derived from a national clinical audit [7]. Data extracted included demographic data (age, gender), time-series vitals at a rate of one value per minute (intracranial pressure, mean arterial pressure, temperature), laboratory results (natremia, hemoglobin, oxygen arterial partial pressure), clinical evaluation at admission (Glasgow coma scale, pupillary abnormalities), treatment received (sedative drugs, osmotherapy, surgical management), mortality and length of ICU stay. Vitals monitoring in the ICU often includes artifacts, leading to potential outliers. To address this, outliers outside the 1st to 99th quantiles were excluded using a rolling 1-hour frame in the time-series data. Within these time-series, periods shorter than 10 minutes of missing data were imputed using spline interpolation. For non-time-series data, missing values in continuous variables were imputed using the last observation carried forward (LOCF) method. For each continuous variable, percentage of adherence to guidelines was defined as the percentage of time where each value remained within recommended range over the entire ICU stay's duration of each patient. The dashboard was created using the flexdashboard R library, figures were created using the Plotly R library. The project's source code is available upon request from the corresponding author.

3. Results

Among 208 patients screened for inclusion: 189 were included in the analyses (153 male patients [79.3 %]; median [Q1 - Q3] age 48.5 [28.3 – 61.8] years). Thirteen patients were excluded because ICP-monitoring duration was inferior to 20 minutes, and 4 patients aged under 18 years old were excluded. Out of 39 selected recommendations, 30 were excluded: 9 focused on clinical and paraclinical diagnostic methods for severe traumatic brain injury, 4 on intracranial pressure monitoring, and 17 for other reasons such as pediatric care, management after the first 7 days or difficulties in extracting information from the CDW. Nine recommendations were ultimately retained, corresponding to 14 variables (Table 1). The median percentage of missing data across all time-series was 0.2 %, with individual patient data ranging from a minimum of 0 % to a maximum of 2.9 % missing. The dashboard is divided into two pages: the first page displays characteristics of patients at ICU admission, including demographic data, severity scores, Glasgow coma scale (Figure 1), and the second page provides access to guidelines adherence

(Figure 2). Compliance to recommendations is plotted over the selected population as the percentage of time biological and vitals data remained within the recommended ranges, illustrated through density plots and boxplots. Concerning therapeutics, sedation is presented as the average dose in µg/kg/min, while other treatments are shown as the percentage of patients who received them during the first seven days after ICU admission. The user can select the period of interest using a slider. Plots can be displayed or hidden using a dropdown menu. Subsets of patients can be selected: patients treated with craniectomy, patients treated with barbiturates, and deceased patients.

Table 1. Selected guidelines, sources and related variables.

Guideline	Source	Variable	Recommended range
Correct systemic factors of secondary cerebral insults	SFAR	Natremia	135 – 145 mmol/L
		Oxygen partial pressure	80 - 200 mmHg
		Hemoglobin	> 8 g/dL
		Mean arterial pressure	> 65 mmHg
		Carbon dioxide partial pressure	35 - 45 mmHg
		Temperature	36 - 37,8°C
Monitor serum glucose concentration	SFAR	Glycemia	8 – 11 mmol/L
Aim for a CPP target between 60 and 70 mmHg	BTF, SFAR	Cerebral perfusion pressure	60 – 70 mmHg
Treat ICP above 22 mmHg	BTF, SFAR	Intracranial pressure	< 22 mmHg
Increase analgesia if ICP is elevated	BTF, SFAR	Sedation doses	/
Use mannitol to control raised ICP	BTF	Osmotherapy	/
Administer high-dose barbiturates to manage elevated ICP	BTF	Barbiturate coma therapy	/
Recommend bifrontal DC for severe TBI patients with ICP elevation	BTF, SFAR	Decompressive craniectomy	/
Consider CSF drainage to reduce ICP	BTF, SFAR	External ventricular drainage	/

CPP, cerebral perfusion pressure; ICP, intra-cranial pressure; DC, decompressive craniectomy; TBI, traumatic brain injury; CSF, cerebro-spinal fluid.

4. Discussion

Dashboards have already been shown to help improve adherence to guidelines [8]. Although few dashboards have been developed in the field of intensive care and anesthesiology, they have shown high acceptance and usability among clinicians [9, 10]. To our knowledge, this dashboard is the first to assess guideline compliance in severe TBI patients. It provides clinicians with a no-code interface that can easily be customized without any programming skills. It simplifies population characterization by summarizing patient features in one interactive panel. Selection based on admission date and clinical characteristics allows the user to investigate discrepancies in guidelines adherence and identify their causes. Our dashboard, focusing on a population with severe

traumatic brain injuries, can also be used for other neurointensive care patients, such as patients admitted for subarachnoid hemorrhage or malignant cerebral infarction.

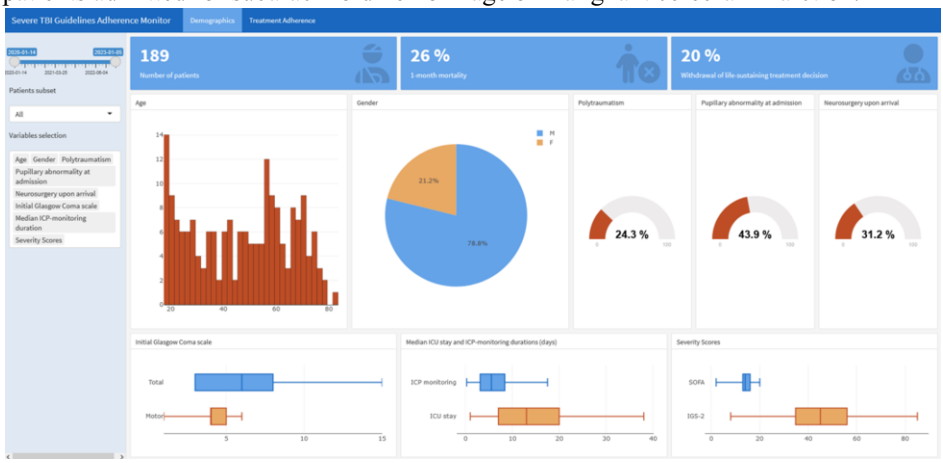

Figure 1. First dashboard page displaying characteristics of patients at ICU admission

Our work has several limitations. First, this dashboard's interoperability is limited because it is not built on a common data model. Second, we displayed only specific recommendations, for which extraction and evaluation were most relevant and consensual. Third, we designed this dashboard according to our experience as clinicians, but it has not been yet validated by other independent experts. Fourth, the quality of the data extracted from the CDW has not been directly evaluated in comparison with data extracted from electronic health records. Future directions for our research therefore include using a Common Data Model (CDM), such as Observational Medical Outcomes Partnership (OMOP) [11] or Fast Health Interoperability Resources (FHIR) [12] to enhance our dashboard's interoperability and sharing capabilities. The interface will be tested by clinicians using the System Usability Scale [13]. Additionally, data from the CDW will need to be compared with that from the EHRs. Finally, the contribution of the dashboard would also need to be prospectively assessed to determine if the information it provides can improve the prognosis for patients admitted with severe traumatic brain injury.

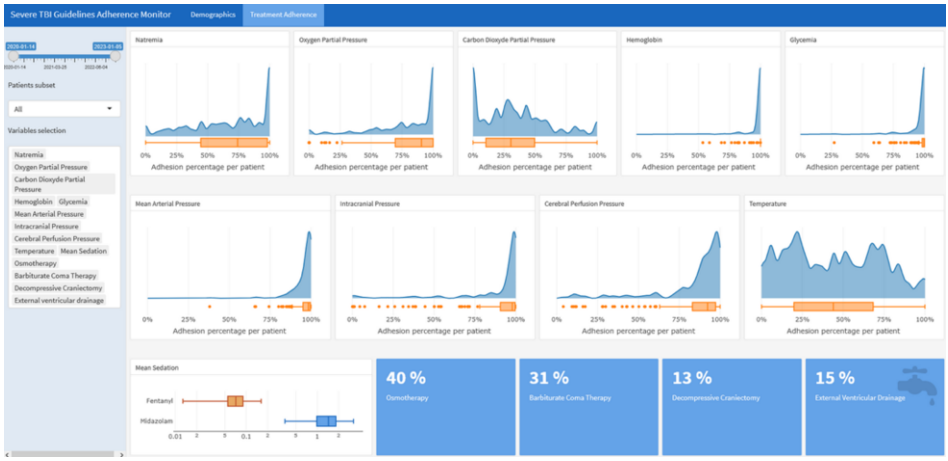

Figure 2. Second dashboard page displaying adherence to guidelines

5. Conclusions

Our dashboard provides clinicians with a user-friendly tool to assess adherence to guidelines for severe traumatic brain injury, using visual tools to highlight key data. More guidelines will be implemented. Its interoperability will be improved using a common data model, and the interface will be evaluated by clinicians.

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