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Research Article

Clinical Significance of Jugular Bulb Venous Oxygen Saturation Monitoring in Severe Traumatic Brain Injury

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Abstract

Background: Maintaining adequate brain oxygenation is a primary goal in the management of severe traumatic brain injury (TBI). Jugular venous oxygen saturation ($SjvO_2$) monitoring is a useful technique for estimating the global balance between cerebral oxygen supply and metabolic demand. The Full Outline of Responsiveness (FOUR) score is a newer consciousness assessment tool that has been proposed as an alternative to the Glasgow Coma Scale (GCS) for evaluating neurological status in patients with severe traumatic brain injury, particularly those requiring mechanical ventilation. **Methods:** A total of 60 patients with severe TBI admitted to the emergency department were included in this study. Jugular venous oxygen saturation ($SjvO_2$) samples were collected every 24 hours until 72 hours after admission. The FOUR score assessment was performed immediately after each $SjvO_2$ sample collection. Spearman's rank correlation analysis was used to evaluate the correlation between $SjvO_2$ and FOUR score. Regression analysis was performed to identify predictors of mortality. **Results:** Among the 60 patients, a weak positive correlation between $SjvO_2$ and FOUR score was observed at admission ($r = 0.251$, $p = 0.061$). However, strong and moderate negative correlations were observed at 48 hours ($r = -0.524$, $p < 0.001$) and 72 hours ($r = -0.62$, $p = 0.001$) after admission. Both the FOUR score ($p < 0.001$) and $SjvO_2$ ($p = 0.026$) were identified as independent predictors of mortality in patients with severe TBI. **Conclusion:** A significant negative correlation between $SjvO_2$ values and FOUR score was observed at 48 and 72 hours after admission. Both $SjvO_2$ and FOUR score can serve as independent predictors of mortality in patients with severe traumatic brain injury.

Keywords: Jugular venous oxygen saturation, severe traumatic brain injury, FOUR score, cerebral oxygenation, mortality prediction.

Introduction

Therapeutic strategies in patients with severe traumatic brain injury (TBI) are primarily focused on preventing a cascade of events known as secondary brain injury, which can exacerbate the primary brain damage once it has occurred. Among the various secondary insults, hypoxia is one of the most critical factors affecting patient outcomes. The detrimental impact of hypoxia on neurological outcome has been well established. [1] The Brain Trauma Foundation, in its Guidelines for the Management of Severe Traumatic Brain Injury (2007), recommended that hypoxia ($PaO_2 < 60$ mmHg) should be strictly avoided in patients with severe TBI. [2]

However, the role of hyperoxia in the management of traumatic brain injury remains controversial. Some studies have demonstrated beneficial effects of

hyperoxia, including improvements in physiological parameters, [3,4] whereas other studies have reported that excessive oxygen levels may lead to worsened functional outcomes. [5,6]

To prevent hypoxia and maintain airway patency, endotracheal intubation (ETI) using a rapid sequence intubation (RSI) protocol was introduced into prehospital Emergency Medical Services (EMS). This approach is intended to secure the airway and prevent aspiration in patients with traumatic brain injury. Although aggressive early airway management has increased the success rate of prehospital ETI, several studies have reported a paradoxical increase in mortality rates. [7,8] The suggested explanations for this finding include hyperventilation [9] and positive pressure ventilation, [10] both of which may adversely affect hemodynamic parameters, leading to cerebral ischemia and poorer functional outcomes in patients with TBI.

Jugular venous oxygen saturation ($SjvO_2$) monitoring is one of the techniques used to estimate the balance between cerebral oxygen delivery and metabolic demand. By measuring oxygen saturation in the jugular venous blood, clinicians can indirectly assess global cerebral oxygenation and detect episodes of cerebral hypoxia or ischemia. [11–13]

For more than four decades, the Glasgow Coma Scale (GCS) has been the most widely used clinical tool for assessing the level of consciousness and neurological status in patients with head injury. Its major advantages include simplicity, ease of use, and the absence of a requirement for specialized diagnostic equipment. [14] However, the GCS has several limitations, including interobserver variability and the inability to assess the verbal response component in intubated patients. In addition, the GCS does not evaluate brainstem reflexes, respiratory patterns, or the need for mechanical ventilation, which may better reflect the severity of neurological impairment. [15]

The Full Outline of Responsiveness (FOUR) score is a newer consciousness assessment scale developed by physicians at the Mayo Clinic in 2005. This scale evaluates four neurological components: eye response, motor response, brainstem reflexes, and respiration. [11,12] Compared with the GCS, the FOUR score provides more detailed neurological information, allows recognition of locked-in syndrome, and enables better assessment of brainstem function and breathing patterns, as well as the detection of different stages of brain herniation. [11]

By expanding neurological evaluation through more comprehensive and measurable parameters, the FOUR score has the potential to provide a more detailed and reliable assessment of the level of consciousness in critically ill patients with severe traumatic brain injury.

Methods

The aim of this study was to determine the correlation between jugular venous oxygen saturation ($SjvO_2$) and the Full Outline of Responsiveness (FOUR) score, and to assess whether these parameters act as independent predictors of mortality in patients with traumatic brain injury (TBI).

This study was conducted from January 2025 to February 2026 in the Intensive Care Unit (ICU) of the Department of Anesthesiology at Venkateshwara Institute of Medical Sciences, Gajraula, Uttar Pradesh, India. Ethical approval for the study was obtained from the institutional research ethics committee. Written informed consent was obtained from all patients or their legal guardians prior to enrollment.

Patients aged 10 to 70 years presenting with severe traumatic brain injury and admitted to the emergency department (ED) were included in the study. Patients with cyanotic congenital heart disease, chronic obstructive pulmonary disease (COPD), brainstem death at admission, or contraindications to single-lumen catheter insertion were excluded.

Jugular venous oxygen saturation ($SjvO_2$) samples were obtained through a single-lumen catheter inserted into the jugular bulb on the side corresponding to the brain's pathological lesion. Blood samples were collected at admission, and at 24, 48, and 72 hours after admission. Immediately after each blood sample collection, the FOUR score was assessed by the observer. Patients who required sedation for brain resuscitation purposes were excluded from the study to avoid interference with neurological assessment. Data normality was assessed using the Kolmogorov–Smirnov test. The correlation between $SjvO_2$ and FOUR score was analyzed using Spearman's rank correlation test. A p-value ≤ 0.05 was considered statistically significant. Linear regression analysis was performed to identify independent predictors of mortality.

Results

A total of 60 eligible patients were included in the study. The baseline characteristics of the study population are presented in Table 1. The median age was 32 years, with 42 patients (70%) male and 18 patients (30%) female. Among the study population, 49 patients (81.7%) underwent surgical intervention, while 11 patients (18.3%) were managed conservatively in the ICU. Overall, 43 patients (71.7%) survived and were discharged, whereas 17 patients (28.3%) died during ICU treatment. At the time of admission, a weak positive correlation between $SjvO_2$ and FOUR score was observed ($r = 0.251$, $p = 0.061$). After 24 hours of admission, the correlation between $SjvO_2$ and FOUR score was $r = 0.562$ ($p = 0.075$). However, both correlations were considered statistically non-significant due to p-values greater than 0.05.

Significant negative correlations were observed at 48 hours and 72 hours after admission. At 48 hours, a strong negative correlation was found ($r = -0.524$, $p < 0.001$), while at 72 hours, a moderate negative correlation was observed ($r = -0.62$, $p = 0.001$), as shown in Table 2. Linear regression analysis was performed to identify variables that significantly predicted mortality. As presented in Table 3, both $SjvO_2$ ($p = 0.026$) and FOUR score ($p < 0.001$) were found to be statistically significant independent predictors of mortality in patients with severe traumatic brain injury.

Table 1 Sample characteristics

Variables		**Number**	**Percentage**
Sex	**Male**	**42**	**70**
	Female	**18**	**30**
Age (years), median (IQR)		**31**	**51.7**
BMI (kg/m2), median (IQR)		**12**	**20**
Procedure underwent, n (%)	Surgical	**49**	**81.7**
	Conservative/nonsurgica	**11**	**18.3**
Patient outcome, n (%)	Survivor	**17**	**28.3**
	Non-survivor	**43**	**71.7**

Abbreviations: IQR, interquartile range; BMI, body mass index.

Table 2 Spearman's correlation between SjvO2 and FOUR score

Time	r-value	P-value
Upon arrival	**0.251**	0.061
24 hours post arrival	**0.562**	0.075
48 hours post arrival	-0.524	**0.001**
72 hours post arrival	-0.62	**0.001**

Notes: r, Spearman's correlation; *statistically significant.
Abbreviations: SjvO2 , jugular venous oxygen saturation; FOUR, Full Outline of Responsiveness.

Table 3 Regression analysis results to detect mortality predictor

Variables	B	P-value	OR	95% CI for OR	
				95% CI for OR	Upper limi
Age	**-0.24**	**0.43**	**0.96**	**0.93**	**1.022**
MAP	**-0.15**	**0.73**	**0.98**	**0.92**	**1.051**
FOUR score	**-0.63**	**0.0001**	**0.97**	**0.86**	**0.997**
SjvO2	**-0.54**	**0.0026**	**0.94**	**0.41**	**0.781**

Note: *Statistically significant.
Abbreviations: MAP, mean arterial pressure; OR, odds ratio; CI, confidence interval; FOUR, Full Outline of Responsiveness; SjvO2 , jugular venous oxygen saturation

Discussion

Jugular venous oxygen saturation ($SjvO_2$) measurement provides valuable information regarding the balance between cerebral oxygen supply and metabolic demand. Oxygen that is not utilized by the brain returns to the systemic circulation through the internal jugular vein; therefore, measurement of $SjvO_2$ helps determine the relationship between cerebral blood flow (CBF) and the cerebral metabolic rate of oxygen ($CMRO_2$). [16]

The normal range of $SjvO_2$ is 55–75%. Values below 55% indicate inadequate cerebral blood flow, which may result from hyperventilation, reduced cerebral perfusion pressure, or cerebral vasospasm, or may occur due to increased cerebral metabolic demand. In contrast, $SjvO_2$ values above 75% may occur in conditions such as cerebral hyperemia, reduced cerebral metabolic activity caused by neuronal cell death or mitochondrial dysfunction, or microvascular shunting due to impaired oxygen extraction and diffusion in damaged brain tissue. Both low and high $SjvO_2$ values are associated with poor neurological prognosis. [12,16]

The Full Outline of Responsiveness (FOUR) score, a relatively new consciousness assessment scale, offers several advantages for patients treated in the intensive care unit (ICU), particularly those requiring mechanical ventilation. Unlike the Glasgow Coma Scale (GCS), the FOUR score does not include a verbal response component, making it more suitable for assessing intubated patients. [11–12,15] The FOUR score evaluates four neurological domains: eye response, motor response, brainstem reflexes, and respiration. [11–12] Therefore, the FOUR score may be a promising method for evaluating the level of consciousness in intubated patients in the intensive care setting.

This study was conducted to determine the correlation between $SjvO_2$ and FOUR score in patients with severe traumatic brain injury. A weak positive

correlation was observed at admission and at 24 hours after admission, although these correlations were not statistically significant. This finding may be explained by the fact that many patients were sedated during the early phase of treatment to facilitate brain resuscitation, which may have influenced neurological assessment.

In contrast, moderate-to-strong negative correlations were observed at 48 and 72 hours after admission. These results are consistent with the study conducted by Sharf and El-Gebali, which reported a strong positive correlation between $SjvO_2$ and GCS in all cases ($r = 0.85$, $p < 0.001$) and among surviving patients ($r = 0.74$, $p < 0.001$). Their study also reported significant correlations at 48 and 72 hours after admission, suggesting that the FOUR score and GCS share similar characteristics in reflecting changes in cerebral oxygenation status. [17]

Previous studies have also demonstrated the prognostic significance of $SjvO_2$ monitoring. Gopinath et al. reported a correlation between jugular venous oxygen desaturation and final neurological outcome in patients with traumatic brain injury. Poor neurological outcomes occurred in approximately 90% of patients with recurrent $SjvO_2$ desaturation episodes, whereas poor outcomes were observed in only 55% of patients without desaturation events. [18]

Similarly, Cormio et al. evaluated 450 patients with severe head injury treated in a neurosurgical intensive care unit. They found that 25.6% of patients with increased $SjvO_2$ experienced good recovery or moderate disability, 25.6% developed severe disability, and 48.8% died or remained in a vegetative state. [19] These findings suggest that $SjvO_2$ should be maintained within the optimal range, as both decreased and increased values are associated with poor neurological outcomes.

In the present study, both $SjvO_2$ and FOUR score were identified as significant predictors of mortality. Similar findings were reported by Sharf and El-Gebali, who demonstrated that GCS ($p = 0.008$) and $SjvO_2$ ($p < 0.001$) were significant predictors of mortality in patients with traumatic brain injury. [17]

One limitation of this study is the relatively small sample size, which may limit the generalizability of the findings. Future studies with larger study populations may provide more comprehensive information regarding the relationship between $SjvO_2$ and FOUR score and their role in predicting outcomes in patients with severe traumatic brain injury.

Conclusion

Jugular venous oxygen saturation ($SjvO_2$) demonstrated a significant correlation with the FOUR score at 48 and 72 hours after admission in patients with severe traumatic brain injury. Both $SjvO_2$ and FOUR score were found to be significant independent predictors of mortality. Further research involving larger sample sizes is required to better understand the relationship between $SjvO_2$ and FOUR score, and to evaluate their association with long-term neurological outcomes, such as those measured by the Extended Glasgow Outcome Scale (GOSE).

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