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Secondary Systemic Insults (ACSOS) in Severe Traumatic Brain Injury (TBI)

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Abstract

Introduction: Severe Traumatic Brain Injury (TBI) remains both frequent and serious in low-resource settings. Secondary Systemic Brain Injuries (SSBI) are physiological disorders (cardiovascular, respiratory, metabolic) occurring after an initial brain injury that aggravate the initial lesions and are life-threatening. They include hypotension, hypoxia, hypo/hypercapnia, anaemia, hypo/hyperglycaemia, hypo/hyperthermia, and cerebral oedema, causing further ischaemia and cellular damage. **Objective:** The objective of this study was to evaluate the impact of secondary systemic insults (ACSOS) on the prognosis of severe TBI in the Emergency Department. **Methodology:** This was a descriptive and analytical cross-sectional study conducted in the Emergency Department of Gabriel-Touré University Hospital (Bamako) from 1 February 2024 to 28 February 2025. It included all patients with severe TBI (Glasgow Coma Scale ≤ 8). Data entry and analysis were performed using SPSS 22.0, with graphs generated in Excel. Qualitative variables were compared using the Chi-square or Fisher's exact test depending on sample size, with a significance level set at $p < 0.05$. Informed consent was obtained. **Results**: During the study period, 19,991 patients were admitted to the Emergency Department, including 1500 cases of TBI (7.5%), of which 430 were severe (28.6%). The population was predominantly young (mean age 27 ± 17 years) and male (76%). Road traffic accidents accounted for 64.7% of cases, with 90% of patients transported by firefighters. Clinical and biological findings included loss of consciousness (89%), hypoxia (19%), anaemia (23.3%), and hypernatraemia (9.8%).

Brain CT was performed in all cases, and transcranial Doppler (TCD) in 48% of severe TBI cases. Management included neurosedation (100%), mechanical ventilation (100%), osmotherapy (45%), and surgery in 21% of cases—mainly decompressive craniectomy (10%) and haematoma evacuation (5%). Complications occurred in 45% of admissions, primarily ventilator-associated pneumonia (25%), sepsis (15%), and urinary tract infections (5%). The mortality rate was 60.7%, with a mean hospital stay of 10 ± 5 days. Female sex (RR 1.22; $p = 0.027$), age over 40 years ($p = 0.001$), and certain secondary systemic insults—particularly hypoxia, anaemia, hyperglycaemia, and hypernatraemia (RR 1.22 - 1.41; $p \leq 0.031$)—were associated with increased mortality. Among complications, ventilator-associated pneumonia and urinary tract infections were highly lethal (RR ≈ 1.7; $p < 0.001$). **Conclusion**: Early identification and correction of secondary systemic insults are crucial to improving the prognosis of severe TBI.

Keywords

Prognostic Factors, ACSOS, Severe TBI, Emergency Department, Gabriel-Touré University Hospital

1. Introduction

Traumatic Brain Injury (TBI) is defined as damage to the skull or brain resulting from an external mechanical force [1]. It is classified according to the Glasgow Coma Scale as mild (13 - 15), moderate (9 - 12), or severe (≤ 8) [2]. With approximately 65 million cases reported in 2021, TBI represents the third leading cause of death and disability worldwide [3]. In Europe, the incidence reaches 235 new cases per 100,000 inhabitants, of which 80% are mild, 10% moderate, and 10% correspond to around 25 severe TBIs per 100,000 inhabitants [4]. In Mali, TBI accounts for nearly 2000 hospitalisations per 100,000 inhabitants [5].

Among severe TBI patients, prognosis mainly depends on secondary systemic brain insults (ACSOS), such as hypo-/hypertension, hypo-/hypercapnia, hypoxaemia, anaemia, thermal dysregulation, and glucose imbalance [6] [7]. Hypotension and hypoxia affect up to 30% - 40% of patients, with higher rates when prehospital management is delayed or inadequate [8]-[10]. Early prevention and correction of these insults are therefore essential, although particularly challenging in resource-limited settings. This study aimed to assess the impact of secondary systemic insults (ACSOS) on the prognosis of severe TBI patients managed at the Emergency Department of Gabriel-Touré University Hospital, Bamako.

2. Methodology

This was a prospective descriptive and analytical cross-sectional study conducted in the Emergency Department of Gabriel-Touré University Hospital (Bamako) from 1 February 2024 to 28 February 2025. All patients admitted with severe TBI (Glasgow Coma Scale ≤ 8) during the study period were included after obtaining informed consent. Data were collected using a standardised form and focused on secondary systemic brain insults (ACSOS), defined as follows: Hyponatraemia < 135 mmol/L; Hypernatraemia > 145 mmol/L, Hypoglycaemia < 0.54 g/L; Hyperglycaemia > 1.98 g/L, Hypotension ≤ 90 mmHg; Hypertension ≥ 140 mmHg, Hypothermia < 35˚C; Hyperthermia > 38.3˚C, Hypocapnia < 35 mmHg; Hypercapnia > 45 mmHg, Anaemia < 10 g/dL; Hypoxaemia < 60 mmHg. Gasometric measurements were not systematically available for all patients. Data entry and analysis were performed using SPSS version 22.0, with graphs produced in Microsoft Excel. Qualitative variables were compared using the chi-square test or Fisher's exact test, depending on sample size, with a significance threshold set at $p < 0.05$. The Relative Risk (RR) and its 95% Confidence Interval (CI) were calculated to assess the strength of association between systemic secondary insults and mortality or other prognostic outcomes. The study protocol received approval from the Ethics Committee of the Faculty of Medicine and Dentistry (Point G), and patient confidentiality was strictly maintained throughout the study.

3. Results

Over the 18-month study period, the Emergency Department of Gabriel-Touré University Hospital managed 19,991 patients, among whom 1500 (7.5%) presented with a Traumatic Brain Injury (TBI), including 430 severe cases (28.6%). The mean age was 27 ± 17 years (range: 2 - 80 years), with the 21 - 40 year group being the most represented (43.7%) (**Table 1**). The sex ratio was 3.73 (male predominance). More than one-third of the injured patients were pupils or students (35.8%). Road traffic accidents accounted for 64.7% of the causes, mainly car-to-motorbike collisions (36.4%) (**Tables 2-3**). Transportation was provided by firefighters in (48.3%) of cases (**Table 4**), and most victims came from urban areas (70%). The mean admission delay was short for urban patients (33 ± 26 minutes) but longer for others (12 ± 4 hours). Clinically, 89% of patients had lost consciousness, and 4% presented a lucid interval, lasting more than 20 minutes in 44%. Convulsive seizures occurred in 6% of patients (lasting 30 - 60 seconds in 77%). The general condition was altered in 94%, with respiratory distress (59%) and **Table 5** hypoxia (19.4%). A motor deficit was recorded in 4%, and associated osteoarticular injuries were found in more than three-quarters of cases. Biological disturbances were moderate: hypernatraemia (9.8%) and hyperkalaemia (2.3%). Anaemia, however, affected nearly one-quarter of patients and represented the most frequent secondary systemic insult (ACSOS) (28.9%) (**Table 6**). Brain imaging mainly showed haemorrhagic oedematous contusions (83.5%), often associated with depressed skull fractures (80.9%) (**Table 7**). Transcranial Doppler (TCD) was performed in 48% of cases, revealing intracranial hypertension in 95% of examinations. Regarding management, initial stabilisation (urinary and nasogastric catheter placement) was systematic. Mechanical ventilation was required in 70% of patients. Analgesia was almost universal (98.6%), and neurosedation was mainly achieved with midazolam (93.8%). Surgical intervention was necessary in 21% of cases, predominantly decompressive craniectomy (63.7%). Complications were common, particularly pressure sores (93.9%) (**Table 8**), Ventilator-Associated Pneumonia (VAP: 92.3%), and urinary tract infections (53.6%), which were the major causes of morbidity. The overall mortality rate was 60.7%; only 9.6% of patients were discharged alive from the emergency department, while 23.7% were transferred, mainly to neurosurgery. The hospital stay was less than 10 days in more than 70% of cases. Bivariate analysis (**Table 9**) revealed that female sex (RR = 1.22; $p = 0.027$) and age over 40 years ($p = 0.001$) significantly increased the risk of death. Among complications, pressure sores, VAP, and urinary tract infections were highly lethal (RR ≈ 1.7; $p < 0.001$). Concerning secondary systemic insults (ACSOS), hypoxia, anaemia, hyperglycaemia, and hypernatraemia also increased mortality (RR = 1.22 to 1.41; $p \leq 0.031$). Conversely, no ACSOS was significantly associated with surgical indication, except for a trend with anaemia ($p = 0.050$) **Table 9**. These findings highlight the crucial impact of systemic failures and secondary complications on the prognosis of severe TBI in resource-limited settings.

Table 1. Age group.

Age group	Number	Percentage (%)
1-20 years	162	38.0
21 - 40 years	**190**	**43.7**
41 - 60 years	54	12.7
61 - 80 years	24	5.6
Total	430	100.0

Table 2. Distribution of patients according to the circumstances of occurrence.

Circumstances	**Number (n)**	**Percentage (%)**
Road Traffic Accident (RTA)	280	64.7
Fall from height	102	23.7
Assault or physical violence	30	7.0
Unknown circumstances	18	4.2
Total	**430**	**100.0**

Table 3. Distribution of patients according to the mechanism of Road Traffic Accident (RTA).

RTA Mechanism	**Number (n)**	**Percentage (%)**
Car-motorbike collision	102	36.4
Motorbike skidding	68	24.3
Car-car collision	60	21.4
Single-car accident	30	10.7
Motorbike-pedestrian	20	8.7
Total	**280**	**100.0**

Table 4. Distribution of patients by means of transport.

Means of transport (vector)	Effectifs	Percentage (%)
Fire brigade	**210**	**48.3**
Taxi	102	23.9
Ambulance (non-medical)	78	18.3
Personnel car	40	9.4
Total	**430**	**100.0**

Table 5. Distribution of patients according to ACSOS observed during clinical examination.

ACSOS	Number (n = 345)	Percentage (%)
Hypoxia	67	19.4
Hyperthermia	63	18.3
Hypotension	52	15.1
Hypertension	50	14.5
Hypothermia	40	11.6

Table 6. Distribution of patients according to biochemical ACSOS.

ACSOS (Biological)	Number (n = 345)	Percentage (%)
Anaemia	100	28.9
Hyperglycaemia	82	23.7
Hypoglycaemia	74	21.4
Hyponatraemia	54	15.6
Hypernatraemia	71	20.6

Table 7. Distribution of patients according to CT scan findings.

CT Findings	Number (n = 430)	Percentage (%)
Haemorrhagic oedematous contusion	356	83.5
Depressed skull fracture	342	80.9
Subarachnoid haemorrhage	296	69.5
Subdural haematoma	202	47.4
Extradural (epidural) haematoma	190	44.6
Pneumocephalus	150	35.2
Intraparenchymal haematoma	100	23.4
Diffuse cerebral oedema	15	3.5

Table 8. Distribution of patients according to the type of complications.

Complications	Number (n = 280)	Percentage (%)
Pressure sores	263	93.9
Ventilator-Associated Pneumonia (VAP)	260	92.3
Urinary tract infections	150	53.6
Convulsive seizures	40	14.3
Brain herniation	30	10.7
Meningoencephalitis	20	7.1
Pulmonary embolism	2	0.7

Table 9. Association between ACSOS and mortality.

ACSOS	Mortality—Yes	Mortality—No	Total	p-value	RR [95% CI]
Hypoxia	53 (18.4%)	14 (9.9%)	67	0.031	1.22 [1.06 - 1.41]
Hyperthermia	40 (13.9%)	23 (16.2%)	63	0.623	-
Hypotension	41 (14.2%)	11 (7.7%)	52	0.074	-
Hypertension	37 (12.8%)	13 (9.2%)	50	0.335	-
Hypothermia	26 (9.0%)	14 (9.9%)	40	0.918	-
Anaemia	85 (29.5%)	15 (10.6%)	100	0.000	1.39 [1.19 - 1.62]
Hyperglycaemia	80 (27.8%)	10 (7.0%)	90	0.000	1.41 [1.21 - 1.65]
Hypoglycaemia	55 (19.2%)	19 (13.4%)	74	0.147	-
Hyponatraemia	38 (13.2%)	16 (11.3%)	54	0.628	-
Hypernatraemia	61 (21.2%)	10 (7.0%)	71	0.000	1.38 [1.18 - 1.62]

4. Comments and Discussion

4.1. Limitations of the Study

- The difficulties encountered during the study were marked by the absence of pre-hospital medical care (medicalized ambulances with trained medical personnel on board) to provide early treatment before arrival at the hospital, which could improve patient prognosis.
- Intracranial Pressure (ICP) monitoring using a pressure sensor was not performed in these patients due to the lack of this valuable tool, which could not be replaced by Transcranial Doppler (TCD) to determine cerebral hemodynamics.
- We were unable to perform blood gas tests on patients with severe head trauma due to the lack of dedicated equipment or the absence of notification of hypoxemia and/or hypercapnia/hypocapnia as major ACSOS reported by several authors. To this end, we used pulse oximetry (SPO2) to interpret hypoxia rather than hypoxemia.

4.2. Discussion

The prevalence of severe Traumatic Brain Injury (TBI) in our study (28.6%) remains markedly higher than that reported by Sagbo *et al.* in Gabon (7.04%) and Ogondon *et al.* in Côte d'Ivoire (16.9%) [11] [12]. Recruitment through the Emergency Department—acting as the single entry point for trauma victims prior to triage—favours the inclusion of a greater number of severe cases, particularly during peak activity periods when intensive care unit beds are saturated. In contrast, the Gabonese and Ivorian series originated from intensive care units, where patient admission depended on bed availability and stricter transfer criteria, which mechanically reduced prevalence rates. The 21 - 40-year age group accounted for 43.7% of cases, confirming the vulnerability of a professionally active population exposed to high-risk behaviours such as frequent mobility, motorcycle use, and alcohol consumption [5] [11]. The mean age (27 years) aligns with findings from the Ivorian and Beninese studies (≈ 31 - 34 years) [12] [13], reflecting a regional trend. The strong male predominance (sex ratio 3.73) illustrates men's higher exposure to occupational and road-related accidents; all regional studies confirm this disparity, with ratios ranging from 1.4 to 7.6 [12]-[14]. Students and pupils (35.8%) represented the most affected socio-professional category, whereas taxi drivers predominated in Côte d'Ivoire (32.3%), and traders and students shared first place in another Malian series [12] [15]. Such differences mirror the diversity in urban density, transport patterns, and socio-professional structures across countries. Road traffic accidents (RTA) were the leading cause (64.7%), mainly car-to-motorbike collisions (36.4%). The widespread use of motorcycles—fast, affordable, but poorly protected vehicles—explains this predominance. In Gabon, however, car-to-pedestrian collisions (77.3%) were most common, highlighting the influence of urban design and local road behaviour [11]. The mean admission delay (≈ 33 minutes) was far shorter than that reported in Benin (9 hours) or Gabon (15 hours) [13] [11]. The urban proximity of Bamako and the prompt response of the fire brigade (involved in 48.3% of transfers) likely contributed to this, although the absence of pre-hospital medical support continues to limit early stabilisation. Clinically, hypoxia was the most frequent secondary systemic insult (19.4%), followed by thermal and haemodynamic disorders, while anaemia (28.9%) and stress-induced hyperglycaemia (23.7%) were the predominant biochemical disturbances. These ACSOS impair cerebral perfusion and metabolism and represent well-established poor prognostic factors [16]. Their distribution differs from the Gabonese series, where hyperthermia (60%) and anaemia (29.5%) were most threatening [11]—likely due to the humid tropical climate and limited temperature regulation. Older Malian studies primarily reported hypotension (12% - 33%), reflecting longer pre-hospital delays [5] [15]. The high rate of haemorrhagic oedematous contusions (83.5%) and intracranial hypertension (95% on transcranial Doppler) indicates high-kinetic trauma. Lower rates reported in Côte d'Ivoire (contusions: 36.6%) or Mali (57%) may be explained by limited CT scan availability or different imaging thresholds [12] [5]. Although the use of transcranial Doppler (48%) remains suboptimal, it proved valuable for confirming intracranial hypertension and guiding treatment. Approximately two-thirds of patients (70%)

received mechanical ventilation and neurosedation with midazolam, consistent with international recommendations. However, invasive monitoring remains incomplete: central venous lines were placed in only 60% of patients, and arterial catheterisation was rarely available, limiting haemodynamic optimisation. Regional comparisons show diverse management strategies; in Benin, targeted fluid resuscitation and more frequent transfusions were reported [13], reflecting differences in lesion profiles and local resources. Morbidity was dominated by pressure sores (93.9%) and ventilator-associated pneumonia (VAP: 92.3%), both typical of prolonged immobility and invasive ventilation. These complications exacerbated the high mortality rate (66.7%), comparable to Beninese data (67.3%) but higher than in Côte d'Ivoire (51%) and Cameroon (39.7%) [12]-[14]. Female sex, age > 40 years, hypoxia, anaemia, hyperglycaemia, hypernatraemia, and infectious or cutaneous complications emerged as independent predictors of death, partially corroborating other African findings that identified hypotension and hyponatraemia as major prognostic determinants [13] [17] [18].

5. Conclusion

Prognostic analysis highlights the adverse role of several ACSOS, particularly oxygenation, hemoglobin, blood glucose, and sodium disorders, which are clearly associated with excess mortality. These results confirm that, beyond the initial severity of the trauma, prevention, early detection, and rigorous correction of ACSOS must be a central focus of care in order to improve the prognosis for severe head trauma in the African context.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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