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Original Article

Severe head trauma in children: Analysis of 68 cases in light of current guidelines

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Abstract

Aim: To assess the characteristics of severe head trauma in the pediatric age group and to analyze its results under the current guideline.

Material and Methods: Eighty pediatric patients (<18 years) admitted to our hospital with the diagnosis of severe head trauma and treated by neurosurgery and the pediatric intensive care unit (ICU) between 2014 and 2018 were analyzed retrospectively. Of these, 68 patients who met the study criteria were selected. Besides the demographic data of the patients, the presenting neurologic, clinic, radiologic and laboratory findings were recorded. Then the association between these variables and 1-year Glasgow Outcome Scale (GOS) scores was analyzed.

Results: There is a correlation between the presenting GCS scores and 1-year GOS scores of the patients when grouped as favorable (4-5) and unfavorable (1-3). Regarding the other admission findings, the patients with hypothermia, the patients with hyperglycemia, the patients to whom CPR was applied, the patients with pupillary areflexia, the patients with hypoxia and the patients with neurological deterioration have lower 1-year GOS scores. There was no difference between the gender, age, type of injury, type of trauma (isolated head trauma or multiple trauma), presence of shock on admission, having hematoma surgery, having decompressive craniectomy, treatment with ICP monitoring and 1-year GOS scores. The overall mortality rate was 29.4% (20 patients), and the rate of poor prognosis (GOS 1-3) was 48.5% (33 patients).

Conclusion: Children with severe head trauma should be treated at centers that are experienced in the field per updated guidelines. Since the morbidity and mortality rates of severe head trauma are still high, efforts toward improving preventive measures should also be considered.

Keywords: Children; prognosis; Glasgow Outcome Scale; guideline; severe head trauma

INTRODUCTION

Traumatic brain injury (TBI) is the leading cause of morbidity and mortality in children in developed countries. The hospitalization rate of children with a traumatic brain injury was reported as 70/100,000 in the U.S. Nearly 5% of the children exposed to head trauma have severe TBI, which is described as a Glasgow Coma Scale (GCS) score of less than 9 in a patient with TBI (1). An increased rate of preventive measures and concomitant developments in resuscitative medicine have helped reduce the morbidity and mortality in recent decades (2,3).

Characteristics of TBI in children have some differences from those in adults since the child has a developing brain. Since the skull and cerebral substance inside are more compressible in children, traumatic forces result in diffuse axonal damage rather than hemorrhagic masses (2,4). However, there are not satisfactory data revealing how commonly intracranial pressure (ICP) monitoring is used in severe pediatric head traumas in Turkey (5). Secondary injuries caused by increased ICP have been depicted as the fundamental reason behind morbidity and mortality in pediatric severe TBI. As a result, successful

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ICP control has proven to be the best strategy to reduce morbidity and mortality (7).

Morbidity and mortality rates of severe TBI in children remain high despite all the developments in preventive strategies and medical management. Treating the children with severe TBI in well-equipped and experienced pediatric ICUs and complying with updated guidelines seem to be the best strategies, as emphasized in the recently updated guideline (6). We present our experience of 68 patients with severe TBI treated in a multidisciplinary fashion under the guidance of the current guideline by the departments of neurosurgery and pediatric ICU of our hospital.

MATERIAL and METHODS

Patients

Eighty patients under the age of 18 (8) who were admitted to the pediatric ICU with the diagnosis of severe head trauma (GCS <9) between 2014 and 2018 were retrospectively analyzed. Of these, 68 cases with full records and 1 year of GOS follow-up data were included. Besides the patients' demographic data, clinical findings, radiologic and laboratory results, neurosurgical interventions and ICP values were examined from the hospital records. Afterward, patients' 1-year GOS values were recorded by calling the families.

Monitoring

The neurosurgery team performed surgical intervention when there was surgery-requiring pathology in the first CT examination (Figure 1a-b). If a non-surgical condition appeared, the next issue was whether to perform ICP monitoring. CT scoring methods are used to decide which patients to monitor for ICP instead of conducting routine ICP monitoring (9,10,11).Therefore, ICP monitoring was not performed on patients with low degrees of cisternal compression and without a prominent midline shift. The patients who directly underwent bilateral decompressive craniectomy and hematoma surgery were also not considered for ICP monitoring (Figure 1a-b). An ICP monitoring device with a fiber-optic catheter was placed on the frontal lobe parenchyma from the right Kocher point to monitor ICP and CPP (Integra Camino®Pressure Monitoring Catheter Kits) (Figure 2a-c). The patients to whom ICP monitoring was not applied were closely followed with periodical neurologic and radiologic examinations (CT and MRI).

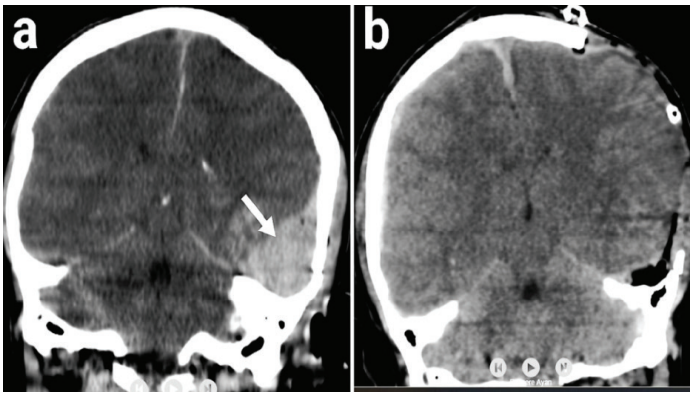

Figure 1. a) Left temporal acute subdural hematoma (white arrow) and linear fracture are seen in coronal non-enhanced cranial CT image. b) Coronal non-enhanced cranial CT image of the same patient after the successful evacuation of hematoma and ipsilateral decompressive craniectomy

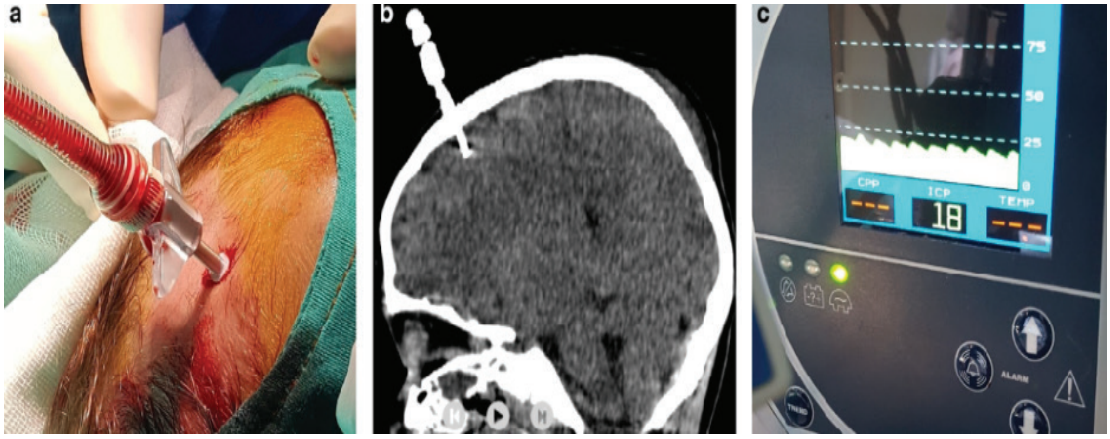

Figure 2. a) Image revealing that ICP monitoring catheter is implanted to the right Kocher point of the patient. b) Sagittal non-enhanced cranial CT image showing implanted ICP monitoring catheter. c) ICP monitor revealing the ICP value of 18 mmHg

Medical Treatment

If the patient had already been sedated at admission, a neurologic examination was performed after the cessation of the sedative drug and the end of its effect. ICP decrease was achieved with medical treatment in patients with high ICP values or high brain CT scores according to guidelines with specified sequence and doses. If the patient was under the treatment of sedation, it was stopped periodically to record neurological examinations and assess the treatment results. In the case of neurologic deterioration, a brain CT was repeated and evaluated by a neurosurgeon. A cranial MRI scan was taken to determine the extent of the

cerebral damage in patients with a preliminary diagnosis of diffuse axonal injury (Figure 3a-d).

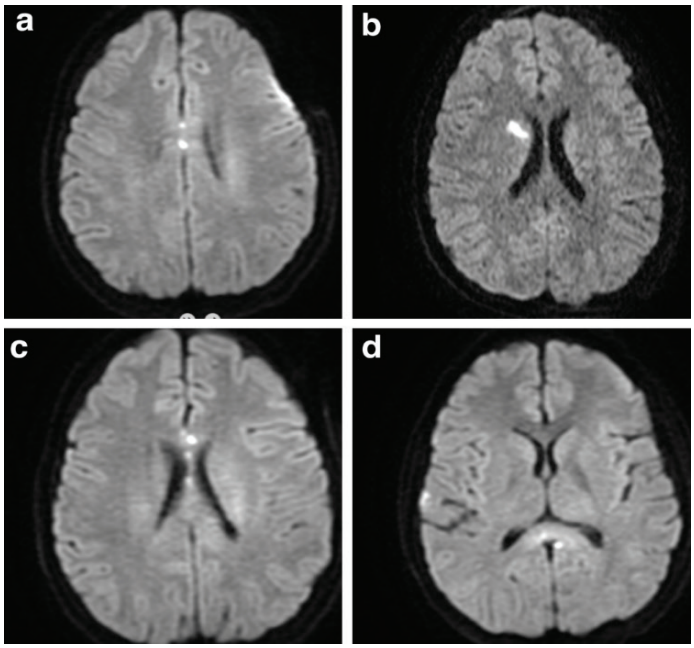

Figure 3. a-d) Diffusion-weighted MR images of 4 different patients suffering from a diffuse axonal injury

Surgical Treatment

Patients with acute hematoma, hydrocephalus and depressed skull fracture underwent emergency operations by the neurosurgery team. In patients with diffuse brain edema observed during hematoma surgery, ipsilateral decompressive craniectomy was added. An early brain CT was taken and assessed when patients had a high risk of deterioration. Patients with high ICP values (> 20mm Hg) that did not decrease despite maximal medical treatment underwent bilateral decompressive craniectomy in the first 2 days of trauma (Figure 4a-b). Early cranioplasty (within 3-6 months) was performed in patients who survived decompressive craniectomy. However, early cranioplasty was not considered in children under 5 years of age because of the likelihood of spontaneous closure (Figure 4c-d).

Statistical Analysis

In this study, for statistical analysis, we used SPSS version 22 for Mac OS as well as Python Scipy library (Oliphant, 2007). Python for Scientific Computing. Computing in Science and Engineering 9, 90 (41). Categorical variables are presented as percentages, whereas mean and standard deviation were used to summarize continuous variables. The normality of the continuous measurements was checked using Shapiro-Wilk test. Depending on the normality, ANOVA or Kruskal-Wallis tests were used to compare groups based on GCS. The comparison for categorical variables were made using Pearson's or Fisher's exact chi-square tests depending on the cell counts in the contingency tables. P values of less than 0.05 were considered statistically significant.

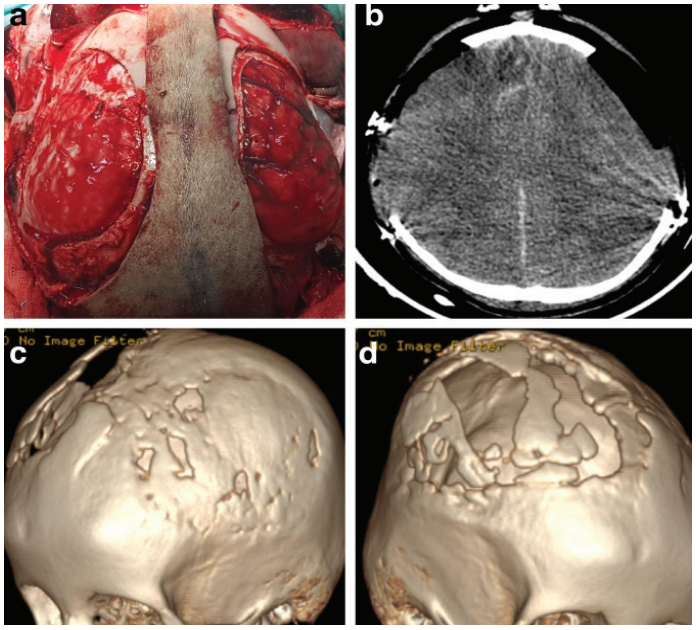

Figure 4. a) Perioperative image of a patient taken during bilateral decompressive craniectomy for traumatic subarachnoid hemorrhage, edema and contusion. b) Postoperative CT image of the same patient revealing effective bony decompression. c) Three-dimensional CT image of the same patient, taken 1-year postoperatively, reveals almost total spontaneous closure of the bony defect at the left side. d) Three-dimensional CT image of the same patient, taken 1-year postoperatively, reveals partial spontaneous closure of the bony defect at the right side. Cranioplasty was not needed in this patient, and she is still under close follow-up

RESULTS

The majority of the 68 cases were males (n=42, 62%) rather than females (n=26, 38%). Gender distribution is not significantly different than random (p=0.052, see Table 1). The age of the cases ranges from 4 months to 16.75 years, with an average of 7.9 ± 5.7 years for boys and 6.5 ± 4.9 years for girls with no statistically significant difference between them (p=0.36).

The distribution of 1-year GOS scores is as follows: 20 cases of GOS 1 (29.4%), 3 cases of GOS 2 (4.4%), 10 cases of GOS 3 (14.7%), 5 cases of GOS 4 (7.4%) and 30 cases of GOS 5 (44.1%). When GOS scores are categorized as unfavorable (GOS 1-3, n=35, 51.5%) and favorable (GOS 4-5, n=33, 48.5%), so that we call gGOS for "grouped" GOS, their distribution is more balanced. Of all the cases, 20 (29.4%) died in the first year. In terms of GOS scores, we did not observe a statistically significant difference in demographic attributes such as gender (p=0.437) and age (p=0.283). Table 1 shows all statistical comparison results.

The most frequent type of injury we observed is a high-level fall in 35 cases (51.5%), followed by motor-vehicle accidents in 23 cases (33.8%) and TV tip-over injuries in 5 cases (7.4%). No strong statistically significant dependence is observed between the type of injury and GCS GOS score and between the type of injury and

mGOS score (p=0.055 and p=0.622878, respectively). Our patients include 27 (39.7%) isolated head trauma cases and 41 (60.2%) multi-trauma cases, and these two groups display no statistically significant difference in terms of 1-year GOS (p=0.609) and admission GCS scores (p=0.092).

We also investigated the relationship between GCS score at the time of admission (entry GCS) and 1-year GOS scores. When GOS scores are measured on a 1-5 scale, no significant relationship has been found between them (p=0.108). However, when GOS scores are grouped into two categories (gGOS) as unfavorable (GOS 1-3) and favorable (4-5), we observed a significant relationship between GCS and 1-year GOS scores (p=0.014). Figure 5 shows a comparison of entry GCS and GOS scores that implies that entry GCS and GOS scores are related. Low entry-GCS patients exhibit low 1-year GOS scores and vice versa. In all, 55% of the patients (11 out of 20) who died in the first year have GCS scores of 3. Also, 11 out of 15 patients with GCS scores of 3 died within a year, two had severe disability, and two survived without severe disability. The overall unfavorable outcome ratio among the patients with GCS scores of 3 is around 86.6%.

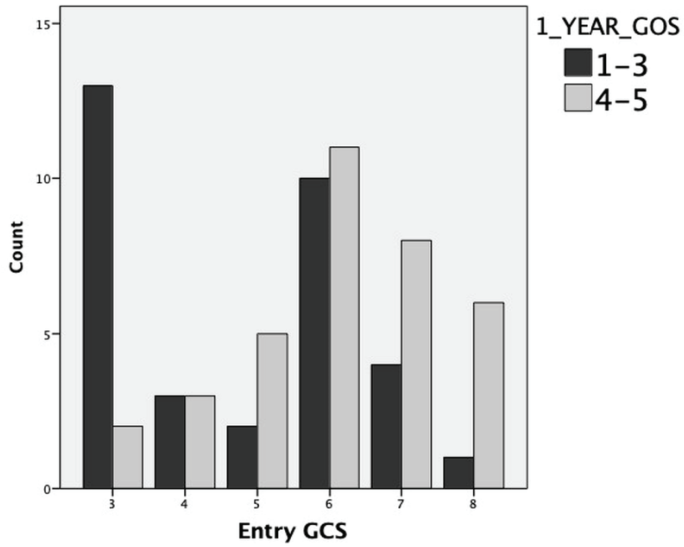

Figure 5. 1-year GOS score versus entry GCS (GCS score at the time of admission to the emergency room). GOS 1-3 corresponds to unfavorable prognosis, whereas GOS 4-5 corresponds to favorable prognosis

The effect of the initial treatment given to patients when they are first admitted to the ER is another important variable. The patients treated with CPR have significantly lower 1-year GOS scores than untreated patients (p=0.0068, Table 1). The patients with pupil reflex have statistically higher 1-year GOS scores than those without pupil reflex (p<0.001). No statistically significant difference is found between 1-year GOS scores of the patients with and without shock when they were first admitted (p=0.184053). The existence of hypoxia in patients is a factor in 1-year GOS scores, i.e., the patients with hypoxia have statistically lower 1-year GOS scores than those without hypoxia (p=0.03312), contrary to insignificant differences for gGOS. Also, patients with neurological deterioration have lower 1-year GOS scores than those without neurological deterioration (p<0.001). Cases with different GOS scores display statistically significant differences in body temperature (p=0.00648), average blood pressure (p=0.048) and blood glucose level (p=0.0044), primarily arising from the differences between the cases with GOS score of 1 and others. Unfavorable cases with low GOS scores have significantly lower body temperature, lower blood pressure and higher blood glucose. It is interesting to note that the significant difference between blood pressures based on GOS score fades away when we use gGOS (p=0.547). Heartbeat values display a peculiar difference in terms of their significance: the difference is not significant for GOS grouping (p=0.078) but is significant for gGOS grouping (p=0.031, heartbeat is lower for the unfavorable GOS group).

Three other patient characteristics we investigated—having hematoma surgery, ICP monitoring and decompressive craniectomy—do not display any statistically significant change in 1-year GOS scores (p=0.639, p=0.852 and 0.289, respectively) (Table 1).

Table 1. Comparison of variables for different GOS groups

Variable	GOS	gGOS
Gender	0.437	0.659
Age	0.283	0.043
Type of injury	0.055	0.622
Isolated head trauma	0.609	0.489
CPR	**0.0068**	**0.025**
GCS	0.108	**0.014**
Pupil reflex	**<0.001**	**0.002**
Shock	0.184	0.185
Hypoxia	**0.033**	0.223
Neurological deterioration	**<0.001**	**<0.001**
Hematoma surgery	0.521	0.444
ICP monitoring	0.704	0.913
Decompressive craniectomy	0.151	0.194
Blood glucose	**0.004**	**<0.001**
Average blood pressure	**0.048**	0.547
Heartbeat (bpm)	0.078	**0.031**
Body temperature	**0.006**	**0.011**

DISCUSSION

It is important to manage treatment by following current guidelines. It is of paramount importance to monitor the patients and assess their treatment with ICP, CPP and imaging methods and to direct the medical treatment accordingly. When necessary, neurosurgery performs surgical interventions in the course of treatment.

Monitoring

Although the importance of ICP monitoring is well known in the management of severe head trauma, when to perform the procedure is still controversial. However, the main approach in advanced centers is to perform ICP monitoring in all patients with severe head trauma (12,13,14). In the series of 96 cases by Jaganathan et al., a correlation between ICP and radiological imaging was reported, and no Marshall grade I patients had ICP elevation (15). Our practice was not to perform ICP monitoring for all patients due to problems in the supply of the monitoring kit, problems in the detection of early GCS due to the presence of sedated patients coming from external centers, lack of algorithm and protocols between neurosurgery and pediatric ICU. In our center, we use CT scoring techniques to select the patients on whom we perform ICP monitoring (9,10,11). After evaluation of these scores, we make a decision to perform ICP monitoring in cases with a high risk of ICP elevation. In this study of 68 cases, ICP monitoring was performed on 20 patients. In the recent guideline, ICP monitoring is suggested for all severe head traumas (6). However, ICP monitoring could not be performed for all patients due to the cited reasons. Although our series is not a randomized controlled study and consists of a small group of patients, the patients with ICP monitoring and the ones without it showed no significant difference regarding their 1-year GOS scores.

Medical Treatment

Hyperosmolar therapy consists of mannitol and hypertonic saline (HTS). Although both are widely used to decrease ICP, the use of mannitol declined with the introduction of hypertonic saline in the 1990s, while the use of hypertonic saline increased (16). Since there are no new randomized studies about mannitol usage, new studies about hypertonic saline increased the usage of HTS in clinical practice. Increased osmolarity is a side effect of both treatments. However, even though it is still controversial, such an increase is better tolerated in children when HTS is used (17,18). Although the recently published fourth edition of the adult severe head trauma guideline states that HTS decreases ICP more effectively in ICP over 25 mmHg, it provided no significant difference with respect to mortality and morbidity (19). In our center, hyperosmolar treatment is used per the pediatric severe head trauma guideline. To decrease ICP, 20% mannitol is used at 0.5-1 gr/kg infusion dose or infusion of hypertonic saline (3% NaCl) at a dosage of 2-5 meq/kg in 10-20 minutes. Blood osmolarity is closely monitored according to pediatric guidelines to overcome the complications of this treatment.

Appropriate usage of analgesics and sedation is crucial in patients' toleration of intubation tubes and mechanic ventilation and also in the prevention of sudden ICP elevation. But all recommendations about the usage of analgesics, sedatives and neuromuscular blocking agents are based on level 3 of evidence, and since their half-life is long, they might suppress the neurological examination. As a new recommendation that was not included in the previous edition of the guideline, bolus usage of midazolam and/or fentanyl to decrease ICP is not suggested because of the risk of decrease in CPP (20). However, long-term propofol infusion is not recommended either for sedation or for refractory ICP elevation.

The seizure threshold is lower in the pediatric age group, and its rate goes up to 70% in severe head trauma (21,22). Prophylaxis for seizure is recommended for early (first 7 days) post-traumatic seizure prevention. Although there is insufficient evidence to show the superiority of levatiracetam over phenytoin (23), in our center, all pediatric head trauma patients are routinely administered a loading dose of 40 mg/kg of levetiracetam and later a maintenance dose of 20 mg/kg/day.

In the recent guideline, hyperventilation treatment has been changed into "ventilation treatment." Hyperventilation, which has been applied for many years to reduce ICP rapidly, results in cerebral vasoconstriction led by hypocapnia and thus decreases ICP. Since it may also cause cerebral hypoperfusion, its use is controversial (24). Therefore, in ventilation treatments, advanced cerebral monitoring should be performed. Ventilation therapy was applied in our center only in cases of persistent ICP elevations despite hyperosmolar agents, sedoanalgesia and muscle relaxants. However, in our study, there was a lack of access to sufficient records about hyperventilation treatment and its results.

Although it is known that moderate hypothermia (32-33°) has an effect on ICP control, according to the new guideline, hypothermia has no superiority over normothermia in terms of outcome (25). On the other hand, it has been shown in animal and clinical studies that hyperthermia increases neurological damage (26,27). We do not use hypothermia as a treatment modality because no data suggest it contributes to survival.

When ICP elevation persists despite all medical and surgical interventions, a high dosage of barbiturate administration is recommended based on a low level of evidence. High dose barbiturate treatment shows its effect by decreasing metabolic need and total cerebral blood volume and also by decreasing ICP. Thus, brain tissue oxygenation improves as a result of directing more blood flow to the place where the metabolic need is the greatest (28). In our series, thiopental—a barbiturate derivative—was used in 8 (40%) patients who underwent ICP monitoring (dose range: 0.5-5 mg/kg/h). Six of 8 patients to whom thiopental infusion was administered had low diastolic blood pressure. Then, crystalloid fluid

(0.9% NaCl) and inotrope (noradrenalin) were administered to increase systemic vascular resistance.

The new guideline recommends enteral nutrition be started in the first 3 days after injury because it reduces mortality and contributes significantly to the outcome (6, 29). However, an immune-system–stimulating diet is not recommended (30). Furthermore, corticosteroids are not recommended because they have neither an ICP-decreasing effect nor a significant effect on prognosis (31). Furthermore, corticosteroid administration is contraindicated in the adult guideline (32).

Surgical Treatment

According to the new guideline, neurosurgical interventions include the evacuation of hematoma, which requires surgery, correction of depressed skull fractures, insertion of an ICP monitoring kit, CSF drainage and decompressive craniectomy. Surgical interventions play a crucial role in preventing herniation syndromes and in decreasing ICP. If the brain seems edematous after hematoma evacuation, the bone flap would not be replaced, and brain parenchyma can be given more space to expand, which also contributes to reducing ICP. Depressed skull fractures, particularly those with open wounds, should also undergo surgical correction. On the other hand, ICP monitoring is preferred in diffuse pathologies such as diffuse traumatic subarachnoid hematoma, diffuse cerebral edema and diffuse axonal injury. If ICP remains above 20 mmHg and does not decrease despite all these medical treatments, then a bilateral wide frontotemporoparietal decompressive craniectomy can be performed within 48 hours (33,34). As well as studies showing no significant difference of decompressive craniectomy regarding morbidity and mortality (1,35), studies also report significant benefits of decompressive craniectomy in terms of morbidity and mortality (36,37). Taylor et al. pointed out that decompressive craniectomy does decrease ICP but does not reduce mortality (38). In our series, decompressive craniectomy was performed on 15 (22%) patients. Based on clinical and neurologic examinations and CT grading scores, 10 patients (67%) underwent decompressive craniectomy in the early period without ICP monitoring. Another 5 patients (33%) underwent decompressive craniectomy upon persistent high ICP despite maximal medical treatment.

The mean value of GCS score of 11 patients who underwent hematoma surgery was 4.7, and their rate favorable prognosis was 36.4%. The mean value of GCS score of 15 patients who underwent hematoma surgery was 4.9, and their rate favorable prognosis was 33.3%. The mean value of GCS score of 20 patients who underwent hematoma surgery was 5.4, and their rate favorable prognosis was 50%. It is noteworthy that there is a correlation between favorable results and high GCS scores of the ICP monitoring group. Unlike the previous edition of the guideline, lumbar drainage recommendation is excluded. On the other hand, external ventricular drainage (EVD) is still recommended. Shapiro and Marmorau (39) reported that ICP decreased with CSF drainage via EVD, but persistent ICP elevation despite all preventions caused death. However, it is not clear whether EVD alone has any effect on decreases of mortality and morbidity (15,40). None of the cases of this series underwent CSF drainage via EVD.

Prognosis

We observed a significant association between GCS and 1-year GOS scores when GOS scores are grouped as unfavorable (GOS 1-3) and favorable (GOS 4-5) outcomes. The overall ratio of unfavorable outcomes among the patients with presenting GCS score of 3 is around 86.6%. The presenting GCS score has a prognostic value, although the number of patients included is not very high.

The patients to whom CPR was applied have lower 1-year GOS scores. The patients with pupillary areflexia have statistically lower 1-year GOS scores than those without it. Hypoxia is another poor prognostic factor related to lower 1-year GOS scores. Also, patients with neurological deterioration have lower 1-year GOS scores than those without neurological deterioration. The patients with lower body temperature and higher blood glucose levels tend to have unfavorable outcomes. As a result, these findings can be recommended as prognostic factors to foresee the possible results of severe head trauma in the pediatric population.

On the other hand, no statistically significant difference was found between demographic data (gender and age), type of injury, trauma being isolated head trauma or multiple trauma, presence of shock on admission, having hematoma surgery, having decompressive craniectomy, treatment with ICP monitoring and 1-year GOS scores.

There are certain limitations of the study. First of all, this study is a retrospective study and does not contain any comparison between different treatment modalities. Another limitation is that the number of cases is limited to make strong conclusions.

CONCLUSION

Pediatric patients with severe head trauma should be treated in medical centers with experienced neurosurgery and pediatric ICU units according to recent guidelines with a multidisciplinary approach. However, after all this effort, severe head trauma patients' morbidity and mortality are still very high, so caution about preventive measures should be taken.

Competing interests: The authors declare that they have no competing interest.

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Ethical approval: This study was approved by the Institutional Ethics Committee and conducted in compliance with the ethical principles according to the Declaration of Helsinki.

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