Critical care management of severe head injury in children

Ağır kafa travmalı çocukların yoğun bakım ünitesinde tedavisi

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AMAÇ
Ağır kafa travmalı çocuklarda sonuç skorunu etkileyecek klinik, travmatik belirleyici faktörlerle ilişkin skalaların birlikteliğinin analizi

GEREÇ VE YÖNTEM
Ocak 1996-Eylül 2003 tarihleri arasında nöroloji yoğun bakım ünitemize başvuran 55 ağır kafa travmalı çocuk hasta retrospektif olarak incelendi. Tüm hastalar acilen bilgisayarlı tomografiyle hastalığın şiddet derecesi ve intrakraniyal travmaların hipoksi, hipotansiyon, hematolojik ve metabolik değişiklikler gibi sekonder nedenleri açısından değerlendirildi. Sonuç analizleri Glasgow sonuç skalasıyla travma sonrası 6. ayda değerlendirildi.

BULGULAR
Otuz bir hasta (% 57) kabul edilemez, 24 (% 43) hasta ise kabul edilebilir sonuç skoruyla iyileşmiştir. Ağır kafa travmalı çocuklarda çok değişkenli analiz ile ortalama sistolik kan basıncı, hipoksi, hipotansiyon varlığı, başvuru anındaki Glasgow koma skoru ve çoklu intrakraniyal lezyon varlığının anlamlı belirleyici faktörler olduğu gösterildi ($p<0,05$) Kafa travmasından sonraki başvuru anındaki lökosit düzeyi ve kan glikoz düzeyleriyle Glasgow sonuç skoru (GOS) arasında istatistiksel açıdan anlamlı bir farklılık bulunamadı.

SONUÇ
Bu çalışma çocuk hastalarda ağır kafa travmasına ilişkin klinik ve radyolojik bulgularla prognostik faktörleri tanımlamaktadır. Ağır kafa travmalı çocuklarda tedavinin hedefleri hasarlanmayı artıracak nedenlerin önlenmesi kafaiçi basıncının normalleştirilmesi, arter kan gazları ve sistemik kan basıncının optimize edilmesidir.

Anahtar sözcükler: ağır kafa travması, pediatrik Glasgow sonuç skoru, prognostik faktörler, Glasgow koma skalası

BACKGROUND
Our aim was to analyze prognostic factors and their association with outcome among children with severe head injury.

METHODS
We conducted a retrospective study among children (n=55) with severe head injury [Glasgow Coma Score (GCS) ≤ 8] who were admitted to our Neurosurgical Intensive Care Unit (ICU) from January 1996 to September 2003. The patients were immediately evaluated with cranial computed tomography (CT) for the severity of head injury as well as for the causes of secondary insults such as hypoxia and hypotension, metabolic and hematological alterations. Outcome analysis was assessed according to Glasgow Outcome Scale Score (GOS) six months after the injury.

RESULTS
A poor result occurred in 31 patients (57%) while 24 patients (43%) had favourable results. Multivariate analysis showed significant independent prognostic effect for admission mean systolic blood pressure, presence of hypoxia, multiple trauma, admission GCS score and multiple intracranial lesions ($p<0.05$). Admission WBC counts and serum glucose levels were not correlated with GOS.

CONCLUSION
This study describes clinicoradiologic findings and prognostic factors regarding severe head injury in pediatric patients. The goals of managements of pediatric patients with severe traumatic head injury include normalizing intracranial pressure, optimizing arterial blood gases and systemic blood pressure, and prevention of factors that exacerbate secondary brain injury.

Key Words: severe head injury, pediatric, Glasgow outcome score, prognostic factors, Glasgow Coma Scale

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INTRODUCTION

Motor vehicle accidents are the leading cause of death in children younger than 18 years of age. In this group, head injury is the most common cause of mortality. [1 -4] Most instances of death occur in the severe brain-injured child with a GCS of 8 or less. The annual brain injury rate per 100,000 children is approximately 185, with boys being twice as likely to be injured as girls.[5 – 7] Approximately one fourth of head injuries in children younger than 2 years of age are inflicted with injuries. [8] Common causes of injuries are falls (35 %), sports and recreation-related injuries (29 %), and motor vehicle accidents (24 %). [9-11]

Eighty-two percent of traumatic brain injuries in children are mild, 14 % moderate or severe and 5 % are fatal while approximately 20 % of survivors suffer significant disability. [10] Most head traumas in children are preventable. Seat belts, helmets and air-bags when used correctly, can either help to eliminate or at least minimize the affects of the impact at the time of injury. [5, 12]

Head injury is responsible for both primary and secondary brain damage. Long term complications can lead to severe disability. The outcome of head injuries depends largely on the extent and nature of primary damage and on the effectiveness of therapy in preventing, or limiting, secondary brain damage. [13- 18]

The causes of secondary insults such as systemic hypotension, hypoxia, and intracranial hypertension have been shown to jeopardize ultimate neurological outcome after brain injury. [7] In several studies involving children with severe head injury, age at the time of injury, post-resuscitation GCS, neurological reflex, duration of coma, post-traumatic seizure and CT scan findings were recorded as the most significant prognostic factors in outcome. [19- 22] An understanding of these factors, in order to reduce their possible negative impact, together with the use of specific guidelines for treatment, can make a significant contribution to improving the prognosis of these patients. [23]

In this retrospective report, we evaluate an institutional series of 55 children with severe head injury and analyze the association of several prognostic factors with outcomes.

MATERIALS AND METHODS

A retrospective review of the Uludag University School of Medicine Department of Neurosurgical ICU medical records for all patients 18 years of age or less who sustained severe brain injury from January 1996 to September 2003 was performed. On admission to the emergency department, type of trauma and GCS, pupillary asymmetry, the causes of secondary insults such as hypoxia and hypotension, radiologic features, and metabolic and hematological disorders were evaluated and their impact on the outcome was analyzed.

All children immediately underwent computed CT of the brain on admission. The severity of head injury was categorized according to the GCS: scores of 8 or less indicated severe head injury. Hypoxia was diagnosed when PaO_2 levels in the arterial blood sample remained under 60 mmHg or $SatO_2$ levels remained under 90 %, as determined with a pulse oximeter, for at least 15 minutes, or when apnea and cyanosis prevailed. Hypotension was diagnosed if the systolic arterial blood pressure (SABP) was lower than the fifth percentile by age for at least 15 minutes, radiological lesions evaluated by an experienced neuroradiologist. The only metabolic alteration considered was glycemia. The blood glucose level of every child was measured on admission and then twice daily during hospitalization. In accordance with the literature, the threshold value used for hyperglycemia was a blood glucose concentration of 150 mg/dl. We excluded patients with associated infection, inflammatory processes, and those who had received any medicine that might alter WBC count.

The outcome was assessed 6 months after the trauma using GOS: a GOS of 1 was applied to the children who died, a GOS of 2 to those with a persistent vegetative state, a GOS of 3 for a severe neurological deficit, a GOS of 4 for a mild neurological deficit, and a GOS of 5 for completely healthy children. GOS 4 and 5 were considered good outcomes, while GOS 1, 2 and 3 were considered poor outcomes. [24]

All children underwent resuscitation procedures and all other maneuvers in agreement with the international literature.[25 – 6] More specifically, in recent years the Brain Trauma Foundation, in cooperation with the AANS, has developed a set of

Table 1: Glasgow Outcome Scores

GOS	n	%
I	12	21.8
II	8	14.5
III	11	20
IV	9	16.3
V	15	27.2

guidelines for the treatment of severe neurotrauma [23, 27, 28] In our institution, children with severe head injuries were monitored and treated in accordance with these international guidelines, modified for age (Figure 1 A, B).

Statistical analysis

Multivariate Logistic Regression Analysis was performed to evaluate the independent effect of demographic factors, GCS, type of trauma, CT findings, clinical presentations such as hypoxia and hypotension. (p= 0,007 for trauma; p= 0,001 for GCS score; p= 0,0231 for hypoxia; p= 0,0243 for CT findings; p= 0,002 for hypotension).The influence of all the clinical and radiological factors on the outcome was assessed using univariate analysis- employing the t test (Fisher's exact test for expected cell values < 5) (p= 0,013 for trauma; p=0,004 for GCS score; p= 0,0234 for hypoxia; p= 0,007 for CT findings; p= 0,047 for hypotension). Univariate risk factors were tested in the multivariate models. Multivariate predictors with p< 0,05 were considered significant. All continuous values are presented as mean ± standard error or as mean with 95% confidence interval (CI) unless otherwise stated. All calculations were performed using SPSS 11.5 Version for Windows (Chicago, IL).

RESULTS

Between January 1996 and September 2003, 55 children (34 boys and 21 girls) with severe head injury were admitted to our neurosurgical ICU. The mean age at the time of head injury was 108±18, 7 months (range 2, 5 months-18 years). The mechanisms of injury were motor vehicle accidents in 28 (51 %), falls in 25 (45 %) and child abuse in 2 (4%) cases. The demographic characteristics of the children at the time of hospital admission are shown in figure 2A,B. Outcomes in terms of GOS were good recovery in 15 (27 %), moderate disability in 9 (16 %), severe disability in 11 (20 %), vegetative state in 8 (15 %) and death in 12 (22 %) patients (Table 1).

There was no significant difference between boys and girls (p>0.05) with respect to GOS scores. Forty children (72.7 %) were affected by isolated head injuries, and 15 (27.3 %) had multiple trauma. There was a significant difference in GOS scores between multiple trauma (MT) and pure head injuries (PT) (p <0.05).

Mean systolic blood pressures obtained on admission were highly correlated with the GOS scores (p<0.05) (Table 2).

Considering the cranial CT features, the most frequent brain lesions were epidural/subdural hematoma in 18 (32.7 %), contusion in 27 (49.1 %) and brain edema in 9 (16.4 %) children (Table 3).

There was a significant difference in GOS scores between solitary (29 patients, 52.7 %) and multiple intracranial lesions (19 patients % 34.5) (p<0.05) (Table 2).

Among the children, GCS scores were 3 to 5 in 9 (16.3 %), 6 to 8 in 46 (83.7 %). The GCS scores obtained on admission were correlated with the GOS scores (p<0.05).

Elevated WBC counts and hyperglycemia were found in 17 (30.9 %) and 44 (80 %) children with head injuries, respectively. Mean WBC counts

Table 2.

Charecteristics of children	n		GOS at 6 months from hospital admission	
			Unfavorable	*Favorable*
GCS at	≤8	55		
admission	6-8	46	21[a]	25
	3-5	9	8	1
Hypoxia	13	12[b]	1	
Hypotension		13	13[c]	-

a The GCS scores obtained on admission were correlated with GOS (p<0.05)
b There was a statistically significant difference between hypoxic and non-hypoxic patients (p<0.05)
c Mean systolic blood pressure obtained on admission were highly correlated with GOS (p<0.05)

Table 3: Computed Tomography Findings (t-SAH : traumatic subarachnoid hemorrhage, DAI :Diffuse Axonal Injury , IVH : Intraventricular Hemorrhage)

CT findings	n
Cerebral Edema	9
DAI	5
Epidural/Subdural Hematoma	18
t-SAH	6
Intraparenchymal	2
Contusion	27
IVH	3

and glucose levels obtained on admission were not correlated with GOS.

DISCUSSION

Trauma is the leading cause of both morbidity and mortality in the pediatric population, and traumatic injures cause >50% of all childhood deaths. Gennarelli and coworkers showed that the overall mortality is three times higher in trauma patients with head injury than in those without intracranial trauma. The cause of death was attributed to brain injury in 67.8 % to extracranial injuries in 6.6% and to both cranial and extracranial trauma in 25.6 % of patients. Severity of head injury still remains the strongest predictor of overall outcome in poli- traumatized individuals. [29, 30]

Although children have better survival rates as compared with adults with traumatic brain injuries, the long-term sequelae and consequences are often more devastating in children due to their age and developmental potential. [12] Children often have more diffuse brain injury, while adult TBI more often involves focal trauma. The reasons for this difference are likely due to the unique biomechanical and tissue properties of the pediatric brain. The immature brain has higher water content and lacks complete axonal myelinization. It is also possible that the increase risk of secondary insults in infants and the young children contributes to the diffuse nature of pediatric TBI. [12] In addition, postmortem studies of pediatric TBI victims often show venous congestion, edema and diffuse axonal injury. [31]

The major causes for moderate and severe brain injuries are motor vehicle accidents, bicycle accidents, and falls. [5,12,14,20,22,23,31] If the brain injuries are grouped based on age of occurrence, different patterns emerge. [6] The most common mechanism of injury varies with age. For example, younger children under 4 years of age most often have TBI secondary to falls, motor vehicle accidents and child abuse. For older children, TBI is most often attributed to motor vehicle accidents and participation in sports. TBI in the teenage population is usually associated with motor vehicle accidents. Motor vehicle accidents were the most frequent causes of trauma, while, compared with other studies, child abuse was rare. [6, 10, 11, 32] Our results were in accordance with those of the literature as for the variations in mechanism.

The prevalence of traumatic brain injury in boys is twice that of girls.[5] In our study severe head injury was found to be more frequent in boys than girls, although no differences in outcome were found. The data from the medical records included 34 boys (62%) and 21 girls (38%). Mortality in these children was similar for both boys and girls. In addition, mortality rates were similar for all ages and showed no statistical differences (p>0,05).

Mass lesions, including subdural hematomas (SDH), epidural hematomas (EDH), and intracerebral hemorrhages, account for a fairly small portion of intracranial pathology in childhood TBI. [33] A significant factor in producing intracranial mass lesions in the neonate is birth trauma. The incidence of mass lesions in pediatric head injuries increases with age. Epidural hematomas occur in 1 to 2.5% of neonates and infants and in 1.5% to 5% of older children and adolescents. [34] Subdural hematomas in the pediatric population vary from 3.5% to 10.8%, whereas the risk of extracerebral hemorrhage is less than 1% to approximately 4%. [35] In our series there were 18 (25.7 %) patients with epidural and subdural hematomas. Most children with EDH present with mild or absent neurologic findings compared with children with SDH, but mortality rate associated with SDH was significantly higher (40.5 % versus 4.3 % for EDH). In our study no death occured due to EDH and two children died because of SDH.

Admission GCS score is related to severity of injury and outcome. [36] Our results also confirm that GCS seems to be the most accurate scoring system for evaluating the severity of injury and predicting the outcome of head injured children.

The main factor influencing the children's outcome was the occurrence of secondary insults, namely hypoxia and hypotension. Hypotension and hypoxia are serious, and potentially preventable, secondary insults significantly increase the mortality and morbidity rates of severe head injury.[37-9] Unfortunately, there is minimal specific evidence to indicate the effectiveness of those prehospital protocols in preventing or minimizing hypoxic and hypotensive insults in improving outcome.[14, 15, 23, 40, 41] Specific threshold values for ideal levels of oxygenation and blood pressure support in the pediatric age group have not been clearly defined. The adult neurosurgical literature has defined hypotension as systolic blood pressure less than 90 mmHg . In children, hypotension can be defined as less than the 5 th percentile of normal systolic blood pressure for age. Pediatric patients may maintain their blood pressure despite significant hypovolemia and clinical signs of shock. Blood pressure should be monitored frequently. Timely fluid resuscitation should be provided to maintain systolic blood pressure in the normal range. Guidelines are warranted to support avoidance or rapid correction of systolic pressure less than the second standard deviation of normal age or of clinical signs of shock, apnea or hypoventilation, cyanosis, oxygen saturation < 90 %, or PaO_2 < 60 mmHg in children with severe head injury Secondary insults such as hypoxia and hypotension and increased intracranial pressure are the leading factors associated with poor outcome, management has focused on developing better ways to improve oxygen delivery and maximize cerebral perfusion pressure.[18,42,43]

Some authors have been concluded that the presence of episodes of hypotension and/or hypoxia prior to hospitalization increased mortality in adult patients with brain injuries, as similar in children and they are closely associated with poor outcome. [37,39] Chiaretti et al. reported that early complications such as posttraumatic hypoxia and hypotension were associated significantly with a poor outcome.[22] Sharples and co-workers highlighted the observation that hypotension , when associated with hypoxia , results in four-fold increases in mortality in head injured children.[42]

Our data confirm that hypoxia and hypotension are significantly associated with a poor outcome in children with severe head injury and they are in accordance with those reported by others.[2, 28, 44, 45]

The correlation between hyperglycemia and severity of head injury has been demonstrated in the literature in adult patients and in animal models,[46] but the results of our study did not show any significant correlation in our patients. Also, variations of WBC counts did not indicate any statistical correlation in our patients, as already observed by other authors. [47, 48]

Fever increases the body's metabolic rate by approximately 10 % to 13 % per degree Celsius. In experimental studies, moderate hyperthermia results in more severe brain damage after fluid percussion injury, and moderate hypothermia is protective. Jones and colleagues found a significant relationship between fever and poor neurological outcome. [30]

Resuscitation of the child with multiple injuries is similar to that for adults, and therapy must be tailored in accordance with variable patient size, emotional maturity, and response to injury . Because this response is rapid and often compensatory, there is greater reliance on noninvasive means to diagnose and manage the injured child. [22, 26] Multi-system trauma is closely related to outcome in children with head injury which was also the case in our series as well. With appropriate initial resuscitation, careful monitoring, and sound clinical judgement, most injured cases will have expectedly good clinical outcomes.

Recent studies have shown a correlation between the outcome and radiological features in patients with severe head injury.[6, 49, 50] Our study shows that multiple intracranial pathological findings on CT are significantly associated with a poor outcome in children with severe head injury. Several authors have suggested that decreasing the interval between injury and evacuation of intracranial mass lesions was associated with improved outcome. [38]

Continuous intracranial pressure (ICP) monitoring for patients with GCS scores of ≤8 are recommended by the adult head trauma guidelines.[51, 52] Although pediatric guidelines for ICP monitoring are still being developed, evidence supports the recommendations of the adult guidelines for children with TBI. Because elevated ICP and lower cerebral perfusion pressure (CPP) contributed to secondary brain injury, ICP monitoring is an important component of monitoring of the child with head injury. [52] Although there are no standards for the threshold for treatment of elevated ICP, treatment of elevated ICP should be initiated at ICPs of >20mmHg for older children and teenagers. For younger children and infants, one can initiate treatment once the ICP has risen above age-appropriate levels (for infants ≥15mmHg; for children <8 years of age, ≥18mmHg). [50, 52]

Global or regional cerebral ischemia is an important secondary insult to the acutely injured brain. Optimization of cerebral perfusion pressure (CPP) defined as ICP subtracted from mean arterial pressure, has gained increased recognition as a therapeutic endpoint in the management of brain-injured children. Cerebral ischemia and decreased delivery of metabolic substrates to the brain can cause serious sequelae. Combined with cerebral edema and systemic hypotension, cerebral vasospasm can also cause regional hypoperfusion within the brain. CPP > 40 mmHg in children with traumatic brain injury should be maintained. A CPP between 40 and 65 mmHg probably represents an age-related continuum for the optimal treatment threshold. There may be exceptions to this range in some infants and neonates .[7,12]

We use this treatment algorithm details as above. Cognitive and behavioral impairments caused most troublesome long-term disabilities to children and their families. Neurosurgeons examine motor functions with GOS but it is not enough to assess the cognitive and behavioral functions. The cognitive impairments are usually not changes in standard measures of intelligence but are specific neuropsychological symptoms resulting in impairments of memory, attention, organization and speed of performance. [52] We suggest that to evaluate with sensible tests for cognitive and behavioral impairments in further studies.

Neurocritical care is a speciality that focuses on the critical management of patients with catastrophic head injury. Brain ischemia and hypoxia are often central causes of brain damage in these patients. Until recently, the only methods widely accepted for monitoring in the neurological intensive care units have been intracranial pressure and cerebral perfusion pressure monitoring. Cerebral blood flow can now be directly monitored using laser Doppler or thermal diffusion techniques. Brain tissue oxygen tension monitoring can provide a focal measurement of cerebral oxygenation. Intracerebral microdialysis can provide information about glucose metabolism and overall health of the neuron. This approach, along with new computer systems for integrating data at the bedside, may change the way patients with brain injury are monitored and treated in the future.[53] Future investigation is also warranted.

CONCLUSION

Our results, in agreement with previous reports in literature show that clinical and neurological examination (GCS), CT scan, simple laboratory tests (glucose level, WBC), arterial blood pressure and blood gases can demonstrate the severity of head injury in order to ameliorate the outcome of children with severe head injury and thus decrease neurological impairment and mortality.

REFERENCES

1. Hahn YS, Chyung C, Barthel MJ, Bailes J, Flannery AM, Mc Lone DG et al. Head injuries in children under 36 months of age. Demography and outcome. Childs Nerv Syst 1988; 4: 34-40.
2. Luerssen TG, Klauber MR, Marshall LF. Outcome from head injury related to patient's age. A longitudinal prospective study of adult and pediatric head injury. J Neurosurgery 1988; 68: 409-416.
3. Sosin DM, Sniezek JE, Waxweiler RJ. Trends in death associated with traumatic brain injury, 1979 through 1992. Success and failure. JAMA 1995; 273: 1778-1780.
4. Herrera EJ, Viano JC, Aznar IL, Suarez JC. Postraumatic intracranial hematomas in infancy. a 16-year experience. Childs Nerv Syst 2000; 16: 585-589.
5. Michaud LJ, Duhaime AC, Batshaw ML. Traumatic brain injury in children. Pediatr Clin North Am 1993; 40 : 553-565.
6. Dopperberg EMR, Ward JD. Pediatric head injury. In: Winn RH, ed. Youmans Neurological Surgery. 5th ed. Philadelphia: Saunders; 2004; 3473-3480.
7. Downward C, Hulka F, Mullins RJ,Piatt J, Chesnut R, Quint P et al. Relationship of cerebral perfusion pressure and survival in pediatric brain-injured patient. J Trauma 2000; 49: 654-659.
8. Duhaime AC, Alario AJ, Lewander WJ, Schut L,

Sutton LN, Seidl TS, et al. Head injury in very young children: Mechanisms, injury types, and ophthalmologic findings in 100 hospitalized patients younger than 2 years of age. Pediatrics 1992; 90: 179-185.
9. Schutzman SA, Greenes DS. Pediatric minor head trauma. Ann Emerg Med 2001; 37: 65-74.
10. Kraus JF, Rock A, Hemyari P: Brain injury among infants, children, adolescents, and young adults. Am J Dis Child 1990; 144: 684-691
11. Childhood injuries in the United States .Division of Injury Control, Center for Environmental Health and Injury Control, Centers for Disease Control. Am J Dis Child 1990; 144: 627-646
12. Mazzola CA, Adelson PD. Critical care management of head trauma in children. Crit Care Med 2002; 30: 393- 401.
13. Bruce DA, Trumble ER, Steers J. Pathophysiology and treatment of severe head injuries in children. In: Choux M, Di Rocco C, Hockley AD, Walker ML (eds) Pediatric neurosurgery, 1st ed. Churchill Livingstone, London: 1999; p. 355-357.
14. Bullock R, Chesnut RM, Clifton G, Ghajar J, Marion DW, Narayan RK, et al. Guidelines for the management of head injury. Eur J Emerg Med 1996; 3: 109-127.
15. Chesnut RM, Marshall LF, Klauber MR, Blunt BA, Baldwin N, Eisenberg HM, et al. The role of secondary brain injury in determining outcome from severe head injury. J Trauma 1993; 34: 216-222.
16. Gordini G, Feoli A, Pasini T,Vinelli M . Cranial trauma and prehospital care. Evaluation of the effectiveness of early treatment. Minerva Anestesiol 1992; 58: 217-220.
17. Adelson PD. Pediatric trauma made simple. Clin Neurosurg 2000; 47: 319-335.
18. Kochanek PM, Clark RS, Ruppel RA, Dixon CE. Cerebral resuscitation after traumatic brain injury and cardiopulmonary arrest in infants and children in the new millennium. Pediatr Clin North Am 2001; 48: 661-681.
19. Anderson V, Catroppa C, Morse S, Haritou F, Rosenfeld J. Recovery of intellectual ability following traumatic brain injury in childhood: impact of injury severity and age at injury. Pediatr Neurosurg 2000; 32: 282-290.
20. Kalff R, Kocks W, Pospiech J, Grote W . Clinical outcome after head injury in children Childs Nerv Syst 1989; 5: 156-159.
21. Glasgow JFT, McGovern SJ. Initial management of the multiple injured Children: structural approach reduces morbidity and mortality. Curr Pediatr 1997; 7: 187-192.
22. Chiaretti A, Piastra M, Pulitano S, Pietrini D, De Rosa G, Barbaro G, et al. Prognostic factors and outcome of children with severe head injury: an 8-year experience. Child's Nerv Syst 2002; 18: 129-136.
23. Palmer S, Bader MK, Qureshi A, Palmer J, Shaver T, Borzatta M, et al. The impact on outcomes in a community hospital setting of using the AANS traumatic brain injury guidelines. J Trauma 2001; 50: 657-664.
24. Jennett B, Bond M. Assessment of outcome after severe brain damage: a practical scale. Lancet 1975; 1: 480-484.
25. Lang EW, Chesnut RM. Intracranial pressure monitoring and management. Neurosurg Clin North Am 1994; 5: 573-587.
26. Dereeper E, Ciardelli R, Vincent JL. Fatal outcome after polytrauma: multiple organ failure or cerebral damage? Resuscitation 1998; 36: 15-18.
27. Brain Trauma Foundation. The integration of brain-specific treatments in initial resuscitation of severe head injury patient. J Neurotrauma 1996; 13:653-660.
28. Maas AI, Dearden M, Teasdale GM, Braakman R, Cohadan F, Ianotti F, et al. EBIC guidelines for management of severe head injury in adults: European Brain Injury Consortium. Acta Neurochir (Wien) 1997; 139: 286-294.
29. Gennarelli TA, SpielmanGM, Langfitt TW, Gildenberg PL, Harrington T, Jane JA, et al. Influence of the type of intracranial lesion on outcome from severe head injury. A multicentric study using a new classification system. J Neurosurg 1982; 56: 26-32.
30. Prabhu SS, Zauner A, Bullock MRR. Surgical management of traumatic brain injury. In: Winn RH, ed. Youmans Neurological Surgery. 5th ed. Philadelphia: Saunders; 2004: p. 5145-5180.
31. Graham DI, Ford I, Adams JH, Doyle D, Lawrence AE, McLellan DR, et al. Fatal head injury in children. J Clin Pathol 1989; 42: 18-22.
32. Moront ML, Williams JA, Eichelberger MR, Wilkinson JD. The injured child. An approach to care. Pediatr Clin North Am 1994; 41: 1201-1226.
33. Albright L, Pollack I, Adelson D. Principles and practice of pediatric neurosurgery. In: Ritter AN, Ward JD, Eds. New York: Thieme; 1999; p. 849-859.
34. Alberico AM, Ward JD, Choi SC, Marmarou A, Young HF. Outcome after severe head injury. Relationship to mass lesions, diffuse injury, and ICP course in pediatric and adult patients. J Neurosurg 1987; 67: 648-656.
35. Leggate JR, Lopez-Ramos N, Genitori L, Lena G, Choux M . Extradural hematoma in infants. Br J Neurosurg 1989; 3: 533-539.
36. Lieh-Lai MW, Theodorou AA, Sarnaik AP, Meert KL, Moylan PM, Canady AI . Limitations of Glasgow Coma Score in predicting outcome in children with traumatic brain injury. J Pediatr 1992; 120: 195 -199.
37. White JR, Farukhi Z, Bull C, Christensen J, Gordon T, Paides C, et al. Predictors of outcome in severely head-injured children. Crit Care Med 2001; 29: 534-540.
38. Miller JD, Sweet RC, Narayan R, Becker DP. Early

insults to the injured brain. JAMA 1978; 240: 439.
39. Brain Trauma Foundation. Resuscitation of blood pressure and oxygenation. J Neurotrauma 1996; 13: 661-666.
40. Reed II RL. Resuscitation of the multiply injured patient. In: Wilkins RH, Rengachary SS, eds. Neurosurgery. Second Ed. New York: McGraw-Hill; 1996: p. 2689-2697.
41. Robertson C. Critical care management of traumatic brain injury. In: Winn RH, ed. Youmans Neurological Surgery. 5th ed. Philadelphia: Saunders; 2004; p. 5103-5144.
42. Sharples PM, Storey A, Aynsley- Green A, Eyre JA . Avoidable factors contributing to death of children with head injuries. BMJ 1990; 300: 87-91.
43. Cooper A, Di Scala C, Foltin G, Tunik M, Markenson D, Welborn C. Prehospital endotracheal intubations for severe head injury in children: a reappraisal. Semin Pediatr Surg 2001; 10: 3-6.
44. Del Castillo MA, Nava Caballero JM. Forecasting survival after acute neurological disease. Current Opinion in Critical Care 2000; 6: 110-116.
45. Levin HS, Aldrich HS, Saydjari C, Eisenberg HM, Foulkes MA, Bellefleur M, et al. Severe head injury in children: experience of the Traumatic Coma Data Bank. Neurosurgery 1992; 31: 435 -443.
46. Rovlias A, Kotsou S. The blood leukocyte count and its prognostic significance in severe head injury. Surg Neurol 2001; 55: 190-196.
47. Eisenberg HM, Gary HE Jr, Aldrich EF, Saydjari C, Turner B, Foulkes MA, et al. Initial CT findings in 753 patients with severe head injury: a report from the NIH Traumatic Coma Data Bank. J Neurosurg 1990; 73: 688-698.
48. Ong L, Selladurai BM, Dhillon MK, Atan M, Lye MS . The prognostic value of GCS, hypoxia and computerized tomography in outcome prediction of pediatric head injury. Pediatr Neurosurg 1996; 24: 285-291.
49. Marshall LF. Head injury: Recent past, present and future. Neurosurgery 2000; 47: 546-561.
50. Gambardella G, Zaccone C, Cardia E, Tomasello F. Intracranial pressure monitoring in children: comparison of external ventricular device with the fibreoptic system. Childs Nerv Syst 1993; 9: 470-473.
51. Adelson PD, Bratton SL, Carney NA, Chesnut RM, Du Coudray HE, Goldstein B, et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents. Intracranial pressure monitoring technology. Pediatr Crit Care Med 2003; 54: 28-30.
52. Sanchez JI, Paidas CN. Childhood trauma: Now and in the new millennium. Surg Clin North Am 1999; 79: 1503-1535.
53. De Georgia MA, Deogaonkar A. Multimodal monitoring in the neurosurgical intensive care unit. The Neurologist 2005; 11: 45- 54.