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The Influence of Definition and Location of Hypotension on Outcome Following Severe Pediatric Traumatic Brain Injury

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Abstract

Objective—To examine the influence of definition and location (field, emergency department [ED] or Pediatric Intensive Care Unit [PICU]) of hypotension on outcome following severe pediatric Traumatic Brain Injury (TBI).

Design—Retrospective Cohort study.

Setting—Harborview Medical Center (level I pediatric trauma center), Seattle, WA over a 5 year period between 1998–2003.

Participants—93 children < 14 years of age with TBI following injury, head abbreviated injury score (AIS) ≥ 3, and PICU admission Glasgow Coma Scale (GCS) score < 9 formed the analytic sample. Data sources included the Harborview Trauma Registry and Hospital Records.

Outcome Measures—The relationship between hypotension and outcome was examined comparing two definitions of hypotension: 1) systolic blood pressure (SBP) < 5th percentile for age and 2) SBP < 90 mmHg. Hospital discharge Glasgow Outcome score (GOS) < 4, or disposition of either death or discharge to a skilled nursing facility were considered poor outcomes. PICU and hospital length of stay (LOS) were also examined.

Results—SBP < 5th percentile for age was more highly associated with poor hospital discharge GOS (p = 0.001), poor disposition (p = 0.02), PICU LOS (RR 9.5; 95% CI 6.7–12.3) and hospital LOS (RR 18.8; 95% CI 14.0–23.5) than SBP < 90mmHg. Hypotension occurring in either the field or ED, but not in the PICU, was associated with poor GOS (p = 0.008), poor disposition (p = 0.03) and hospital LOS (RR 18.7; 95% CI 13.1–24.2).

Conclusions—Early hypotension, defined as SBP < 5th percentile for age in the field and/or ED, was a better predictor of poor outcome than delayed hypotension or the use of SBP < 90 mmHg.

Keywords

blood pressure; brain injury; pediatric trauma; children; head trauma; hemodynamics

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INTRODUCTION

Traumatic brain injury (TBI) is the reason for as many as 400,000 Emergency Department (ED) visits each year and is the leading cause of traumatic morbidity and mortality in children (1). Despite the adverse relationship between hypotension and outcome following severe pediatric TBI, there is no comparison of the commonly used definitions of hypotension nor is there an analysis of the influence of early versus late hypotension on outcome following severe pediatric TBI.

Studies in adult patients have shown that hypotension left uncorrected in the field is associated with worse outcome than hypotension that is corrected prior to arrival in the emergency department (ED) (2). In children, hypotension on admission to the hospital is also associated with poor outcome (3–6). Adjusted for injury severity, children presenting to the ED with hypotension following TBI have a 3 fold higher mortality rate compared to patients with blood pressure appropriate for age (3). However, since there are no data examining the relationship between pre-hospital (field) blood pressure and outcome in children, it is unclear what constitutes low blood pressure immediately following TBI. Additionally, the definitions of hypotension, including location of hypotension, vary by study. This makes it difficult to estimate the true incidence of hypotension and understand the relationship between blood pressure and outcome in pediatric TBI. Finally, since none of the published studies examine blood pressure in severe pediatric TBI longitudinally from the field through Pediatric Intensive Care Unit (PICU) discharge in the same cohort of patients, it is not possible to identify the relative importance of early versus late hypotension in these patients. We designed a study to compare: 1) commonly used definitions of hypotension and 2) examine the influence of location of hypotension in predicting poor outcome following severe pediatric TBI.

METHODS

Study Design

A retrospective cohort study of children with severe TBI was performed following approval by the Human Subjects Review Committee of the University of Washington.

Subjects and Setting

Children less than 14 years of age admitted to Harborview Medical Center (HMC; level I Pediatric Trauma Center over a 5-year period (1998–2003) with a diagnosis of severe TBI were eligible for inclusion in the study. The HMC PICU is a tertiary care facility that is staffed by pediatric intensivists. It is a 27 bed unit and serves a 5 state region in the Pacific Northwest. The HMC Trauma Registry was used to generate a list of children admitted with severe TBI (Head Abbreviated Injury Score [AIS] ≥ 3). Children who died or were extubated in the ED, or who had PICU admission Glasgow Coma Score (GCS) ≥ 9 were excluded from the final analysis. Transfers from an outside facility were included in the analysis.

The following information was abstracted from each patient's medical record: demographic data, injury severity score (ISS), ED GCS and PICU admission GCS, and level of consciousness, independence and disability at hospital discharge. Physiologic markers of secondary insults (hypoxia [PaO₂ < 60mmHg], hypercarbia [PaCO₂ > 45mmHg], hypocarbia [PaCO₂ < 35mmHg], hyperthermia [T > 38.5 C], hyperglycemia [serum glucose > 150 mg/L]) in either the ED or PICU were recorded. First computed tomography (CT) results (within 24 hours of admission), and the presence of coagulopathy (platelet count < 100K, international normalized ratio > 1.5 or documented uncontrolled bleeding) were also recorded. The lowest systolic blood pressure (SBP) value in the field, ED and PICU for every patient were recorded and dichotomized into two groups: 1) SBP < 5th percentile for age and 2) SBP < 90mmHg. In

this study, data from the scene and primary treating hospital prior to arrival to the HMC ED were treated as field data. The lowest blood pressure from the field was recorded.

The primary outcome measures were hospital discharge Glasgow Outcome Score (GOS) (7) and hospital disposition where GOS 1 = death, 2 = persistent vegetative state, 3 = major disability, 4 = moderate disability but independent and GOS 5 = baseline. GOS < 4 reflects poor outcome. We also examined PICU length of stay (LOS) and hospital LOS. Hospital LOS included transfer from HMC to a second acute care hospital and did not include patient rehabilitation care. Poor outcome was defined as hospital discharge GOS < 4 or discharge disposition to either a skilled nursing facility (SNF) or death.

Statistical Analysis

To identify the better definition of hypotension, we defined hypotension as both: 1) SBP < 5th percentile for age and 2) SBP < 90mmHg. Since as little as one episode of hypotension may worsen outcome following TBI (2), the relationship between any hypotension in the field, ED, or PICU and outcome was compared using each of the above two definitions of hypotension. The hypotension definition that better predicted poor outcome was designated as the better definition of hypotension and used in the subsequent analysis to examine the influence of location of hypotension on outcome. To describe the relationship between location of hypotension and outcome, we used the better definition of hypotension at each of the following sites: “field”, “ED”, “field or ED”, “field and ED”, and “PICU”. Blood pressures recorded prior to HMC were considered “field” blood pressures. The influence of early (field, field or ED, or field and ED) versus late (PICU) hypotension on outcome was examined. The relationship between “field and ED” hypotension and outcome was examined to describe the relationship between early hypotension burden and outcome.

We used Poisson regression with robust variance estimates (8) to calculate rate ratios and p-values for the binomial variables (poor hospital discharge GOS and poor hospital disposition). Chi-square tests assessed whether the parameter estimates significantly differed from zero. We estimated the parameters of the continuous variables (PICU LOS and hospital LOS) with linear regression. T-tests assessed whether the parameters significantly differed from zero. Potential confounding variables of the relationship between hypotension and outcome were created to adjust for the occurrence of hypoxia, hypocarbia, hypercarbia, hyperglycemia, and hyperthermia in the ED or PICU, as well as for ISS and extracranial AIS. Chi square tests assessed whether low PICU admission GCS (GCS 3) was associated with the presence or absence of any hypotension. None of these variables were significant confounders and were not included in the final models. Final models were adjusted for age and gender. Analyses were conducted using SAS software (SAS Institute, Cary, NC). Data are presented as mean $\pm$ SD, and Adjusted Rate Ratios with 95% confidence intervals. $p < 0.05$ reflects significance. Quartiles are given for LOS data as 1st quartile (Q1), 2nd quartile (Q2) and 3rd Quartile (Q3).

RESULTS

Patient Characteristics

The HMC Trauma Registry yielded a list of 172 potentially eligible patients. Seventy-nine patients met exclusion criteria, leaving 93 patients suitable for inclusion in the study. Of the 93 records included for study, field data were missing in 5 cases, and PICU data were incomplete in 4 cases. All patients were transported by Airlift Northwest flight nurses and 54 (58%) were transfers from an outside hospital. The mean age of the cohort was 5.7 ± 4.1 years, and 70% were male. In 91 children, the mechanism of trauma was blunt, of which falls (26%) and motor-vehicle collisions (26%) were the most common causes. Five (5%) children were victims of non-accidental trauma. Mean PICU admission GCS was 4.5 ± 2 (GCS motor $3 \pm$

1), and in 61% of the patients the admission GCS was 3 (GCS motor 1). Fifty-nine patients (55%) had extracranial injuries. The average ISS was 24.3 ± 9.9 (median 25; range 9.0 – 54.9). Secondary insults at any time while in the ED or PICU were common (Table 1). Thirty eight patients (41%) had documented intracranial hypertension on PICU admission; all were treated for intracranial hypertension either in the ED or PICU. Thirty one patients (33%) had coagulopathy (international ionized ratio > 1.5 or platelet count $< 100K$) while in the ED or PICU. There were no cases of hypoglycemia and 1 child received cardio-pulmonary resuscitation at some point in their hospitalization.

Comparing Definitions of Hypotension

The incidence of hypotension, occurring at some point during their course of acute care, varied by definition (Figure 1) and was greater when $SBP < 90\text{mmHg}$ was used to define hypotension compared to when $SBP < 5$ percentile for age was used. When compared with $SBP < 90\text{mmHg}$, $SBP < 5^{\text{th}}$ percentile for age better predicted poor outcome, identifying it as the better definition of hypotension (Table 2). Patient characteristics, according to the presence or absence of hypotension, are given in Table 1. While the proportion of patients with GCS 3 was higher in patients with any hypotension compared to patients with no hypotension, this difference was not statistically significant.

Location of Hypotension Using the Better Definition of Hypotension

The incidence of hypotension ($SBP < 5^{\text{th}}$ percentile for age) according to treatment location is given in Figure 2. Nearly 37% (33/89) of patients were hypotensive in either field, ED or PICU. Two children (2.2%) were hypotensive in the field, ED and PICU. Early hypotension occurred in 28% patients, and 17% patients had late (PICU) hypotension. Hypotension in both the “field and ED” was less common (10%; Figure 2). Of the 20 patients who were hypotensive in the field, 45% (9/20) had persistent hypotension in the ED ($p < 0.001$). Conversely, new onset hypotension in the ED was rare (5/88, 5.7%). Although early hypotension did not predict PICU hypotension, 28% (7/25) of those with “field or ED” hypotension, had persistent hypotension in the PICU. New onset PICU hypotension occurred in 9 % (8/89) patients.

Outcomes

Primary outcomes for this cohort were: hospital discharge GOS 3 ± 2 and poor disposition 19%. PICU LOS was 6.8 ± 8.0 days (median 4.0; Q1– 2.0; Q2 – 4.0; Q3– 8.0) and hospital LOS was 12.3 ± 14.2 days (median 7.0; Q1–4; Q2 –7; Q3 –14). Thirty four percent were discharged from the hospital with a GOS < 4 . Overall mortality rate was 14% (13/93).

The association between location of hypotension and outcome is given in Table 3. When examined separately, both field and ED hypotension predicted poor outcome with hospital discharge GOS < 4 . Field hypotension predicted longer PICU and hospital LOS. ED hypotension predicted poor disposition. “Field or ED” hypotension predicted nearly all measures of poor outcome. Although only 9 patients had both “field and ED” hypotension, this indicator of increased early hypotension burden predicted poor outcome in every category. PICU hypotension predicted longer hospital LOS.

DISCUSSION

This study compares 2 commonly used definitions of hypotension in children with severe TBI, and subsequently uses the better of these hypotension definitions to describe the relationship between location of hypotension and outcome. Our main findings are that: 1) the better definition of hypotension was $SBP < 5^{\text{th}}$ percentile for age and 2) early hypotension, documented in the field and/or ED, predicted poor outcome more so than PICU hypotension.

This study provides new information regarding the measure of hypotension and the influence of early versus late hypotension on outcome in children with severe TBI.

The adverse relationship between hypotension and poor outcome in children with moderate and severe TBI has been previously reported, but each study used a different definition of hypotension (3–6). In this study, we have shown that the incidence of hypotension varies according to the definition of hypotension used ($SBP < 5^{\text{th}}$ percentile for age or $SBP < 90\text{mmHg}$). While this may not be surprising, the comparison of definitions is particularly important for young children in whom $SBP 90\text{mmHg}$ may be higher than the $SBP 5^{\text{th}}$ percentile for age (9–12). This means that while using $SBP < 90\text{mmHg}$ to define hypotension might be appropriate in older children, using $SBP < 90\text{mmHg}$ to define hypotension in younger children might overestimate the true incidence of hypotension. To understand the value of one definition over the other, we compared the different definitions of hypotension in the same patients and found evidence supporting the Brain Trauma Foundation's (BTF) recommendation that an age-related blood pressure definition ($SBP < 5^{\text{th}}$ percentile for age) be used to define hypotension in children with severe pediatric TBI.

The design of the current study allowed us to compare the influence of hypotension occurring early versus late in the course of medical care on outcome. While previous studies have separately described the relationship between ED and PICU hypotension on outcome, none serially compared the relative importance of the early period to the PICU period in the same population. Studies examining the relationship between PICU hypotension and poor outcome did not consider field and/or ED hypotension in their analysis (13,14). Our finding that field hypotension predicted ED hypotension may reflect the fact that therapeutic regimens to maintain or restore hemodynamics can be limited in the field. Although not significant, the high incidence of persistent hypotension in the PICU in children who were hypotensive in the field or ED may be due to severity of injury, suggesting that more aggressive measures may be needed to screen and treat children with severe TBI and early hypotension (15). In addition to describing the risk of persistent and new onset hypotension in the ED and PICU based on field hypotension, we report a greater strength of association between hypotension occurring in either the field and/or ED than hypotension in the PICU. This is important since both field and/or ED represent an early period following severe TBI.

Studies of adults have linked early hypotension following TBI with poor outcome (2,16–18). Hypotension occurring at any point from the time of injury through resuscitation has been shown to double the mortality rate (2). Field hypotension has been correlated with fatal outcomes in adults with polytrauma including TBI (16), and minimization of hypotensive episodes in the field has been shown to improve outcome (17). Observations have also been made in experimental TBI where the incidence of hypotension is higher in younger compared to older rat pup (19,20). These data suggest that there is a need for early identification and treatment of hypotension in children with severe TBI.

The initial management of TBI includes protecting the injured brain from secondary insults when cerebral blood flow (CBF) may be compromised and the incidence of impaired cerebral autoregulation may approximate 37% (21–24). When cerebral autoregulation is impaired, cerebral ischemia may ensue if cerebral perfusion pressure (CPP) is low. This is important because adult TBI data suggest that persistently impaired autoregulation is associated with poor outcome (25).

Limitations

The limitations of our study merit discussion. The retrospective nature of this study confined our data collection to what was recorded in the charts, and may contain unavoidable bias / residual confounders. It would have been preferable to have long-term outcome data such as

3, 6 and 12 month GOS or the Fiser scores (26,27) to assess the impact of hypotension. Unfortunately, there is currently no large or national pediatric database that contains serial hemodynamic data from the field through PICU discharge for a set of patients, making the present relatively small study valuable. As current BTF recommendations consider evidence from studies that use both these definitions of hypotension, it makes the current comparative analysis of the 2 most commonly used definitions of hypotension necessary and important. Another possible limitation is the generalizability of our findings to all children with severe TBI since the data are only from one center and since we had a large number of young patients in our cohort. However, since age < 4 years is associated with worse outcomes, and published studies on TBI involve mainly children of older ages, the information in this study may be important for identification of young children with TBI at risk for poor outcome.

While we did not have data from the field, and PICU in all patients, data are missing only from a small number of patients, making our results valid. While it may be more physiologic to use low CPP to define hypotension, we used systolic blood pressure instead of mean arterial pressure (MAP) or CPP data in this study, because of obvious logistic constraints on measuring CPP in the field or possibly ED. Although our data suggest that hypotension burden may adversely impact outcome, given the retrospective nature of this data, the small number of children with hypotension in the field and ED, and the lack of detailed information regarding hypotension severity or duration in each setting, we only analyzed hypotension as a single event. While we have identified a definition of hypotension that predicts poor outcome, we cannot comment on the age-related blood pressure needed to achieve the best outcomes. Finally, we cannot, from this retrospective study, distinguish between the effect of hypotension vs. severe TBI on outcome.

CONCLUSIONS

In the present study, early hypotension, defined as SBP < 5th percentile for age in the field and/or ED, was a better predictor of poor outcome than delayed hypotension or the use of SBP < 90 mmHg following severe pediatric TBI. Early hypotension burden was also associated with poor outcome. This information regarding the influence of measure definition and location of hypotension has potential triage, therapeutic and prognostic implications for physicians managing children with severe TBI immediately following injury.

References

1. Langlois J, Gotsch K. Traumatic Brain Injury in the United States: Assessing Outcomes in Children. Atlanta (GA): National Center for Injury Prevention and Control, Centers for Disease Control and Prevention (CDC); 2001.
2. Chesnut RM, Marshall LF, Klauber MR. The role of secondary brain injury in determining outcome from severe head injury. *J Trauma* 1993;34:216–22. [PubMed: 8459458]
3. Pigula FA, Wald SL, Shackford SR, Vane DW. The effect of hypotension and hypoxia on children with severe head injuries. *J Pediatr Surg* 1993;28:310–16. [PubMed: 8468638]
4. Kokoska ER, Smith GS, Pittman, et al. Early hypotension worsens neurological outcome in pediatric patients with moderately severe head trauma. *J Pediatr Surg* 1998;33:333–38. [PubMed: 9498412]
5. Chiaretti A, De Benedictis R, Della Corte F, Piastra M, Viola L, Polidori G, Di Rocco C. The impact of initial management on the outcome of children with severe head injury. *Child's Nerv Syst* 2002;18:54–60.
6. Vavilala MS, Bowen A, Lam AM, Uffman JC, Powell J, Winn HR, Rivara FP. Blood pressure and outcome after severe pediatric traumatic brain injury. *J Trauma* 2003;55:1039–44. [PubMed: 14676648]
7. Jennett B, Bond M. Assessment of outcome after severe brain injury. *Lancet* 1975;1:480–5. [PubMed: 46957]

8. Zou G. "A Modified Poisson Regression Approach to Prospective Studies with Binary Data,". *Am J Epidemiol* 2004;159:702–706. [PubMed: 15033648]
9. Ruley EJ. Hypertension. In: Holbrook PR, ed. *Textbook of Critical Care*. Philadelphia: WB Saunders; 1993: 602–612.
10. Blumenthal S, Epps RP, Heavenrich R, et al. Report of the task force on blood pressure control in children. *Pediatrics* 1977;59(suppl 52):797–820.
11. Blumenthal S, Epps RP, Heavenrich R, et al. National Heart, Lung, and Blood Institute, Bethesda, Maryland: report of the task force on blood pressure control in children—1987. *Pediatrics* 1987;79:1–25. [PubMed: 3797155]
12. de Swiet M, Fayers P, Shinebourne EA. Systolic blood pressure in a population of infants in the first year of life: the Brompton study. *Pediatrics* 1980;65:1028–1033. [PubMed: 7367116]
13. Downard C, Hulka F, Mullins RJ, Piatt J, Chestnut R, Quint P, Mann NC. Relationship of cerebral perfusion pressure and survival in pediatric brain-injured patients. *J Trauma* 2000;49:654–9. [PubMed: 11038082]
14. Hackbarth RM, Rzeszutko KM, Sturm G, Donders J, Kuldane AS, Sanfilippo DJ. Survival and functional outcome in pediatric traumatic brain injury: A retrospective review and analysis of predictive factors. *Crit Care Med* 2002;30:1630–5. [PubMed: 12130990]
15. Dearden NM. Mechanisms and prevention of secondary brain damage during intensive care. *Clinical Neuropathology* 1998;17:221–8. [PubMed: 9707338]
16. Hill DA, Abraham KJ, West RH. Factors affecting outcome in the resuscitation of severely injured patients. *Aust NZ J Surg* 1993;63:604–09.
17. Gentleman D. Causes and effects of systemic complications among severely head injured patients transferred to a neurosurgical unit. *Int Surg* 1992;77:297–302. [PubMed: 1478813]
18. Fearnside MR, Cook RJ, McDougall P, et al. The Westmead Head Injury Project outcome in severe head injury. A comparative analysis of prehospital, clinical and CT variables. *Br J Neurosurg* 1993;7:267–79. [PubMed: 8338647]
19. Prins ML, Lee SM, Cheng CL, Becker DP, Hovda DA. Fluid percussion brain injury in the developing and adult rat: a comparative study of mortality, morphology, intracranial pressure and mean arterial blood pressure. *Brain Res Dev Brain Res* 1996;95:272–82.
20. Prins ML, Hovda DA. Traumatic brain injury in the developing rat: effects of maturation on Morris water maze acquisition. *J Neurotrauma* 1998;15:799–811. [PubMed: 9814636]
21. Junger EC, Newell DW, Grant GA, et al. Cerebral autoregulation following minor head injury. *J Neurosurg* 1997;86:425–432. [PubMed: 9046298]
22. Sahuquillo J, Munar F, Baguena M, et al. Evaluation of CO₂ reactivity and autoregulation in patients with post-traumatic diffuse brain swelling (diffuse injury III). *Acta Neurochir Suppl (Wien)* 1998;71:233–236.
23. Vavilala MS, Lee LA, Boddu K, Visco E, Newell DW, Zimmerman JJ, Lam AM. Cerebral autoregulation in pediatric traumatic brain injury. *Pediatr Crit Care Med* 2004;5:257–63. [PubMed: 15115564]
24. Paulson OB, Strandgaard S, Edvinson L. Cerebral autoregulation. *Cerebrovasc Brain. Metab Rev* 1990;2:161–191.
25. Lam JM, Hsiang JN, Poon WS. Monitoring of autoregulation using laser Doppler flowmetry in patients with head injury. *J Neurosurg* 1997;86:438–445. [PubMed: 9046300]
26. Fiser DH, Long N, Roberson PK, Hefley G, Zolten K, Brodie-Fowler M. Relationship of pediatric overall performance category and pediatric cerebral performance category scores at pediatric intensive care unit discharge with outcome measures collected at hospital discharge and 1- and 6-month follow-up assessments. *Crit Care Med* 2000 Jul;28:2616–2620. [PubMed: 10921604]
27. Fiser DH, Tilford JM, Roberson PK. Relationship of illness severity and length of stay to functional outcomes in the pediatric intensive care unit: a multi-institutional study. *Crit Care Med* 2000 Apr;28:1173–1179. [PubMed: 10809301]

Figure 1.

The frequency of hypotension varies by definition and was greater when SBP < 90 mmHg was used as the definition of hypotension, regardless of treatment location. The number of patients with hypotension at each site is given for each of the two definitions of hypotension.

Figure 2. Early (field or emergency department) hypotension was more common than field and ED hypotension.

Figure 3.

Table 1

Demographic and Clinical Characteristics of 93 Children with any hypotension (AH) and no hypotension (NH) systolic blood pressure [SBP] < 5th percentile for age and gender). Percentage data are with respect to groups AH and NH.

	N = 93 n (%)	AH (n=34;37%) n (%)	NH (n=59;63%) n (%)
Male	65 (70)	25 (73)	40 (67)
Female	28 (30)	9 (27)	19 (33)
Blunt Trauma	92 (99)	33 (97)	58 (98)
Injury Severity Score	24.3 ± 9.9	28.4 ± 9.0	22.8 ± 10.0
Mechanism of Injury			
Motor Vehicle Crash	24 (26)	9 (26)	15 (25)
Fall	24 (26)	6 (18)	18 (31)
Auto-Pedestrian	15 (16)	8 (24)	7 (12)
Bicycle	7 (8)	2 (6)	5 (8)
Other	23 (25)	17 (50)	6(10)
PICU Admission GCS *			
3	57 (61)	23 (68)	34 (58)
4	1 (1)	0 (0)	1 (2)
5	4 (4)	1 (3)	3 (5)
6	6 (6)	1 (50)	5 (8)
7	14 (15)	6 (18)	8 (14)
8	11 (12)	3 (9)	8 (14)
First CT Findings			
Edema	13 (14)	7 (21)	6 (10)
Contusion	42 (45)	17 (50)	30 (51)
Subdural Hematoma	31 (33)	10 (29)	21 (36)
Subarachnoid Hemorrhage	19 (20)	9 (26)	10 (17)
Diffuse Axonal Injury	13 (14)	6 (18)	7 (12)
Skull Fracture	12 (13)	7 (21)	4 (7)
Epidural Hematoma	11 (12)	2 (6)	9 (15)
Intraventricular Hemorrhage	12 (13)	9 (26)	3 (5)
Tracheal Intubation on Admission	92 (99)	34 (100)	58 (99)
Extracranial Injuries	55 (59)	23 (68)	32 (94)
Any Secondary Insults in ED or PICU			
Hypoxia (PaO ₂ < 60mmHg)	26 (28)	14 (41)	12 (20)
Hypocarbica (PaCO ₂ < 35mmHg)	74 (80)	32 (94)	42 (71)
Hypercarbica (PaCO ₂ > 45mmHg)	48 (52)	18 (53)	30 (51)
Hyperthermia (T > 38.5°C)	48(52)	24 (71)	24 (41)
Hyperglycemia (Glucose > 50mg/dL)	83 (89)	31 (91)	52 (88)
Any Surgery	55 (59)	20 (59)	35 (59)

* Difference between proportion of patients with GCS 3 between the AH and NH groups is not significant (p = 0.25). PICU = Pediatric Intensive Care Unit, GCS = Glasgow Coma scale score, CT = computed tomography.

Table 2

Outcomes Comparing Definitions of Hypotension at any Site (Field, Emergency Department, Field and/or Emergency Department, Pediatric Intensive Care Unit). The better predictor of poor outcome was SBP < 5th percentile for age. These data are adjusted for age and gender. Poor Outcome = hospital D/C GOS < 4, or disposition to either skilled nursing facility or death. The additional number of days spent in the PICU (PICU LOS) and Hospital (Hosp LOS) due to hypotension for each definition of hypotension are given. p< 0.05 reflects significance.

	SBP < 5%	SBP < 90mmHg
Hospital D/C GOS < 4	0.001	0.10
Poor Disposition	0.2	0.79
Additional PICU LOS	4 days (0.03)	2 days (0.3)
Additional Hospital LOS	10 days (0.0009)	5 days (0.1)

Table 3

Poor Outcome by Location of Hypotension. Early hypotension better predicted poor outcome than late (PICU) hypotension. Early hypotension predicted nearly all measures of poor outcome. PICU LOS and Hosp LOS reflect additional number of days spent in the PICU and Hospital due to hypotension. Data are adjusted for age and gender. $p < 0.05$ reflects significance.

SBP < 5th percentile for age	HOSP D/C GOS < 4	POOR DISPOSTION	PICU LOS (p =)	HOSP LOS (p =)
Field $n = 20/88$	0.03	0.15	4 days (0.03)	13 days (.0003)
ED $n = 15/93$	0.001	0.003	3 days (0.2)	7 days (0.1)
Field or ED $n = 26/93$	0.008	0.03	3 days (0.09)	9 days (0.006)
Field and ED $n = 9/88$	0.01	0.02	6 days (0.03)	15 days (0.002)
PICU $n = 15/89$	0.06	0.5	4 days (0.13)	10 days (0.01)