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Impact of Operative Intervention Delay on Pediatric Trauma Outcomes:

Impact of Operative Delay on Pediatric Trauma Outcomes

Giana H Davidson, MD MPH[1,2], **Ronald V Maier, MD**[1,2], **Saman Arbabi, MD MPH**[1,2], **Adam B Goldin, MD MPH**[1,2,5], and **Frederick P Rivara, MD MPH**[1,3,4]

Giana H Davidson: ghd@u.washington.edu; Ronald V Maier: ronmaier@u.washington.edu; Saman Arbabi: sarbabi@u.washington.edu; Adam B Goldin: adam.goldin@seattlechildrens.org; Frederick P Rivara: fpr@u.washington.edu

[1]Harborview Injury Prevention and Research Center

[2]Department of Surgery, University of Washington and Harborview Medical Center

[3]Department of Pediatrics, University of Washington and Harborview Medical Center

[4]Department of Epidemiology, University of Washington and Harborview Medical Center

[5]Department of General and Thoracic Surgery Seattle Children's Hospital

Abstract

Background—Establishing quality indicators is an essential step in improving mortality and disability among pediatric trauma patients. We hypothesized that timing of craniotomy, intracranial pressure (ICP) monitoring for traumatic brain injury and abdominal operation for solid organ injury correlates with a reduced risk of death, shorter length of stay, and reduced risk of requiring assistance at discharge.

Methods—This was a retrospective cohort study of 99,513 pediatric trauma patients using the National Trauma Data Bank.

Results—In patients that had an ICP monitor placed within four hours compared to those whose ICP monitor was delayed, there was no difference in mortality; however, there was a shorter length of stay in the hospital (RR=0.84, 95% confidence interval (CI), 0.72-0.97) and in the intensive care unit (RR= 0.76, 95% CI, 0.66-0.86) in those that survived to discharge. Patients who had craniotomy within 4 hours had higher mortality (RR= 1.98, 95% CI, 1.11-3.51) compared to those that were delayed. After excluding those that died, there was a shorter overall stay (RR=0.69, 95%

Correspondence: Giana H Davidson, at the University of Washington Medical Center, Box 356410, 1959 NE Pacific Street, Seattle, WA 98195, Phone 206 795-3897, fax 206 543-8136, ghd@u.washington.edu.

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CI, 0.59-0.81) and intensive care stay (RR= 0.69, 95% CI, 0.57-0.83). Similar length of stay results were seen in pediatric patients with solid organ injuries. Excluding those that died, length of stay (RR=0.58, 95% CI, 0.47 – 0.73) and intensive care stay (RR= 0.52, 95% CI, 0.37-0.74) were shorter.

Conclusion—Early intervention in those who survive their initial operation is associated with shorter ICU and hospital stay for traumatic brain and solid organ injuries.

Keywords

pediatric trauma; traumatic brain injury; craniotomy; solid organ injury; outcomes

Introduction

Injury continues to be the leading cause of death and disability among the pediatric population. There are significant deficiencies in pediatric trauma care resulting in preventable deaths,[1,2] and previous studies have documented significant variation in the treatment and outcomes of common pediatric injuries[2-5]. Public reporting of hospital outcomes has been increasing and national benchmarks are an important priority in trauma care[6 7].

Previous studies have shown that compliance with Centers for Medicare and Medicaid Services (CMS) quality indicators results in decreased mortality for the targeted population[6,8,9]. These findings have shown an impact much larger than expected suggesting that compliance with Quality Improvement (QI) measures is a marker of an institution overall striving to improve care. Stelfox *et al* showed that there is a lack of evidence-based quality of care indicators for pediatric trauma care, up to half of all pediatric trauma patients have deficiencies in the quality of care provided, and between 6% and 32% of deaths are preventable[2]. Establishing quality indicators in the pediatric trauma population is an essential next step in improving mortality and disability. Since, mortality rates in injured children are substantially lower than adults, survival alone is an inadequate measure of quality. The impact on morbidity of disease specific indicators on processes of care should be evaluated.

Appropriate management of traumatic brain injuries (TBI) leads to improved mortality and improvement in function. However, substantial variation exists in management in children. Decompressive craniotomy has been shown to result in better outcomes than expected and is associated with a better functional prognosis[10]. The significance of TBI on long-term functional outcome of pediatric trauma patients is substantial and there is not definitive agreement about the timing of craniotomy in the pediatric trauma population. The Brain Trauma Foundation Pediatric Guidelines recommend that physicians place intracranial pressure (ICP) monitors within six hours for a severe TBI[11]. Level III data supports craniotomy in the setting of refractory elevated ICP in children[12]. There is growing support that timing of intervention for traumatic brain injuries affects functional outcomes. Recent literature in the adult military population supports early operative intervention for significant traumatic brain injury[13]. In a study of severe traumatic penetrating brain injury in military compared with matched civilian counterparts, DuBose et al found higher rates of early neurosurgical intervention performed in the military cohort were associated with improvement in survival[14].

Current practice guidelines recommend nonoperative management for stable blunt splenic and liver injuries [15,16]. Tataria et al found similar ICU length of stay, hospital length of stay, transfusion requirements, and mortality rates when comparing patients who had an immediate operation compared to those with failed nonoperative management of their solid organ injuries. However, those pediatric patients that underwent immediate operation had a lower GCS and higher ISS[17]. We hypothesized that patients who ultimately require an operative intervention for their traumatic brain injury or solid organ injury will benefit from earlier intervention.

Materials and Methods

Study Design

We conducted a retrospective cohort study using the National Trauma Data Bank (NTDB) to determine if timing of the proposed quality indicators is associated with a reduced risk of death, shorter length of stay in the intensive care unit, shorter total hospital stay, and reduced risk of requiring assistance at discharge. Proposed quality indicators were: 1) Intracranial pressure (ICP) monitoring within 4 hours of presentation to the emergency department for traumatic brain injury compared with greater than 4 hours, 2) Craniotomy within 4 hours of presentation to the emergency department for traumatic brain injury compared to craniotomy done greater than 4 hours, and 3) Abdominal operative management for liver or splenic injury within four hours of presentation to the emergency department compared to those taken to the operating room greater than four hours after presentation.

Data Sources and Patient Selection

Patients (N=99,513) from 576 hospitals were identified in the 2008 NTDB. There were 378 hospitals designated level 1 or level 2 trauma centers which includes 94% of all level 1 hospitals in the US and 17% of level III or IV trauma centers. 118 hospitals were designated level 1 or 2 pediatric trauma centers[18].

We restricted age to less than 18 years with an admission for trauma defined by *International Classification of Disease, Ninth Revision, clinical modification* (ICD9-CM) codes 800-959.9 with at least one injury being outside of the range: 905-909.9 (late effects of injury), 910-924.9 (superficial injury), and 930-939.9 (foreign bodies). We did not include patients admitted with burns, drowning, hanging, on-going CPR on arrival to the ED, dead on arrival to the ED, or gunshot wound to the head.

Statistical Analysis

Our primary outcomes included mortality, complications (surgical infection, abdominal compartment syndrome, acute respiratory distress syndrome (ARDS), acute renal failure (ARF), cardiac arrest, decubitus ulcer, unplanned intubation, systemic sepsis, wound disruption, deep vein thrombosis (DVT), and graft failure), length of stay in the hospital and in the intensive care unit, and requirement for assistance at discharge (skilled nursing facility, physical therapy or occupational therapy, or rehabilitation versus home) which was used as a surrogate for functional status at the time of discharge.

Poisson regression models were used to determine the relative risk of mortality, complications, assistance at discharge, and length of stay. We examined the following as potential confounders: age, gender, systolic blood pressure (SBP) on arrival to the ED, pulse on arrival, maximum head Abbreviated Injury Score (AIS), maximum abdominal AIS, Injury Severity Score (ISS), the motor component of the Glasgow Coma Scale (GCSm) in the ED, mechanism of injury, level of pediatric trauma center and whether a designated pediatric intensive care unit was available at the treatment hospital. Patients were clustered by treatment facility.

In evaluating mortality for all injuries, we excluded those who died in the emergency department. For length of stay and disposition, only those patients who survived to discharge were included in the analyses. For the analysis on patients with solid organ injury who underwent an abdominal operation, we excluded those with an ICD9-CM code including bowel injury (n= 576) because the finding of bowel injury on presentation would significantly change the likelihood and timing of an abdominal operation.

Results

Population demographics and injury profile

The mean age of our trauma population was 9.6 (SD 5.7) years and 33.3% were female. The mean ISS was 7.7 (SD 7.9) and 1.9% (n=1,853) died after arrival in the emergency department or during their hospitalization, and 2% (n=1974) had complications identified during hospitalization.

Traumatic brain injury was identified in 17.8% (n=17,756). Of TBI patients, 81% had a head AIS of ≥ 3 and 5.5% died during their hospitalization. Of those with a traumatic brain injury (TBI), 4.9% (n=876) had an ICP placed and of those placed, 57.2% were placed within four hours of admission. In addition, 5.5% (n=971) of TBI patients had a craniotomy, of whom, 59.4% were taken to the operating room within four hours. Solid organ injury was identified in 7,148 (7.2%) pediatric patients, of whom 13.8% (n=989) had an abdominal operation. For those with an abdominal operation, 68.3% were taken to the operating room within four hours (table 1).

Timing of operative intervention for traumatic brain injury

Comparing patients who had an ICP monitor placed within four hours compared to those whose ICP monitor was delayed greater than four hours, after controlling for age, gender, injury severity, motor GCS, SBP, pulse on presentation to the ED, level of trauma center, and head AIS, there was no significant difference in relative risk of mortality or complications. In addition, we used a requirement for assistance at discharge as a marker for function at discharge and there was no difference found between groups. There was a shorter length of stay in the hospital (RR=0.84, 95% CI, 0.72-0.97) and in the intensive care unit (RR= 0.76, 95% CI, 0.66-0.86) in those discharged alive (table 2).

There was a higher mortality (RR= 1.98, 95% CI, 1.11-3.51) for those patients with a craniotomy within four hours compared to those in which operation was delayed, after adjusting for age, gender, injury severity, vitals on presentation to the emergency department, pediatric trauma center level and presence of pediatric ICU. After excluding those who died, there was a shorter overall hospital stay (RR=0.69, 95% CI, 0.59-0.81) and intensive care stay (RR= 0.69, 95% CI, 0.57-0.83) associated with early versus delayed craniotomy. There was no significant difference in complications (RR=0.83, 95% CI, 0.56-1.22) or in requirement for assistance at discharge (RR=0.87, 95% CI, 0.68-1.12) (table 2).

Timing of operative intervention for solid organ injury

Similar results were seen in pediatric patients with solid organ injuries. There was a much higher mortality seen in the patients who were taken within four hours to the operating room compared to those who had an operation later in their hospitalization (RR= 3.1 95% CI, 0.99-9.75). Length of hospital stay (RR=0.58, 95% CI, 0.47–0.73) and intensive care stay (RR= 0.52, 95%CI, 0.37-0.74) were shorter for those who survived to discharge. As in the traumatic brain injured patients, documented complications (RR=0.67 95% CI, 0.42–1.07) and a requirement for assistance at discharge (RR=0.87 95% CI, 0.64-1.2) trended towards lower rates in the patients operated on within four hours, but results did not reach significance (table 2).

Discussion

In this cohort study, after adjusting for potential confounders including all recognized severity confounders including age, gender, systolic blood pressure (SBP), pulse, maximum head Abbreviated Injury Score (AIS), maximum abdominal AIS, Injury Severity Score (ISS), Glasgow Coma Scale motor component (GCSm) in the ED, mechanism of injury, level of pediatric trauma center and whether a designated pediatric intensive care unit was available at the treatment hospital, we found that operating emergently (within four hours) was associated with an elevated risk of inpatient mortality. Unexpectedly, even though clinically more ill, those with early intervention in the group that survived had a decreased length of stay in the hospital and in the intensive care unit. We did not find a significant difference in complications or a requirement of assistance at discharge but in all groups there was a trend towards lower documented complications and a lower likelihood of requiring assistance at discharge in the groups that had early intervention. The increased mortality is not surprising as those who are the most critically injured are more likely to go emergently to the operating room[13,14,17,19]. While we attempted to adjust for demographic characteristics, severity of trauma, age, facility and gender, this did not completely account for this increased risk of mortality, supporting well-established data that stratification for injury severity does not completely account for differences in the amount of injury, particularity in head trauma[20-23]. Previous studies have shown that those who received craniotomies overall had a lower GCS and higher injury severity than those that did not have a decompressive craniotomy[13,19]. Since mortality is rare in pediatric trauma, it is important to consider outcomes outside of inpatient mortality as markers for quality of care. NTDB is not a population-based sample and is limited by bias inherent in convenience samples;

however, benefit of this large sample allowed us to look at specific timing of procedures and multiple outcomes for pediatric trauma patients.

We would have expected the cohort of emergently operated on patients who survive to have a longer length of stay, more complications, and higher requirement for assistance at discharge, since they were likely to be more severely injured than the delayed operative cohort. We only included patients who survived to discharge in evaluating disposition and length of hospital/intensive care stay to eliminate the bias of early death confounding days of hospitalization. After eliminating those who died in the hospital (the most severely injured), we found that there was a shorter length of hospital stay and intensive care stay in the group who was emergently taken to the operating room and trend towards lower complication risk and requirement for assistance at discharge. In fact, since the incidence of complications overall was 2%, and not different from the mortality of 1.9%, the ability to use incidence of complications as a quality indicator of outcomes is inadequate due to the rarity of the events. While timing is only one facet of optimal care, the length of stay is likely a surrogate for overall care and may well represent factors in addition to the urgency of the operative intervention. However, the findings do further support immediate operative intervention in those patients who ultimately require an operation. In general, a short interval between admission and surgery coincides with aggressive and potentially better care. While other studies have concluded that there may be no detriment to watchful waiting[17,24], in contrast, we have shown that there is a substantial cost associated with delaying intervention. Longer length of stay is a surrogate for complications and delaying an operation for those that ultimately needed one leads to an increased length of stay in the intensive care unit and overall hospitalization even after excluding those who ultimately died.

There is significant variation in operative rates for solid organ injury[1,25-27]. This suggests there may also be variation in timing of intervention in a pediatric designated trauma center compared to an adult trauma center. Therefore, we controlled for pediatric trauma center and pediatric intensive care designations. Avoidance of unnecessary surgery in the injured child is preferable and has improved survival and lessened morbidity. Previous studies have also demonstrated no increase in mortality among patients undergoing a delayed procedure compared to urgent operation. This is counter-intuitive based on studies defining the benefits of the “Golden Hour” and early intervention in adults[28]. Due to the low rate of mortality, measureable differences in mortality are unlikely to be reached, even if present. The critical question is whether the child pays a price while the physician, in attempting to avoid an operation, delays the inevitable with transfusions, additional volume resuscitation and repeated radiologic studies, having committed to a non-operative plan. Here we show a significant decrease in length of stay for those surviving children, who undergo early versus delayed intervention. The critical missing component to permit improved care are better methods to identify patients who will ultimately need an operation early in their resuscitation to prevent the increased morbidity associated with delayed intervention. In addition, more detailed information must be collected to further elucidate how long term function and disability are affected by these potentially unnecessary delays in operating.

For those who survive their hospitalization, early recognition and intervention is critically lacking for many of those ultimately requiring craniotomy and intracranial pressure monitoring for traumatic brain injury and abdominal operation for solid organ injury. In patients requiring an intervention, timing of the operation is critical and earlier intervention is associated with an improved outcome for pediatric trauma patients. The challenge is elucidating markers early in the course of therapy to prevent detrimental delays and enhance rapid intervention for those who require it. These markers will direct further prospective studies using quality measures outside of mortality to improve future pediatric trauma care.

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Table 1

Demographic characteristics, National Trauma Data Bank, 2008 pediatric trauma patients

	Mean	Standard Deviation
N=99513		
Age (years)	9.59	5.74
Male	66120.00	66.66
Female	33068.00	33.34
ISS	7.74	7.85
	Frequency	**Proportion**
Mortality		
Died in ED	676	0.68
Died in Hosp	1,177	1.18
ICU admit from ED	16,460	16.65
Injuries		
Traumatic Brain Injury	17,756	17.84
Liver	3,204	3.22
Spleen	3,577	3.62
Kidney	1,812	1.82
Procedures		
ICP	876	4.9
ICP within 4 hours	372	57.2
Craniotomy	971	5.5
Craniotomy within 4 hours	551	59.4
Abdominal operation with solid organ injury	989	13.8
Abdominal op within 4 hours with solid organ injury	482	68.3
Complications *	1974	1.98
Mechanism of Injury		
Blunt	85439	86
Penetrating	7491	7.54
Other **	6253	6.28

* Complication includes: SSI, abdominal compartment syndrome, ARDS, ARF, cardiac arrest, decubitus ulcer, unplanned intubation, systemic sepsis, wound disruption, DVT, graft failure.

** "Other" includes: accidental poisoning or by gas, liquid, barriers, misadventures in surgical and medical care, late complications, explosion, cause by electricity, overexertion, and Ecode cause listed as "other"

Table 2

Poisson regression: Outcomes of pediatric trauma patients with traumatic brain injury and solid organ injury having an intervention within 4 hours compared to delayed intervention

ICP > 4 hrs compared to ICP placement within 4 hours in patients with TBI	**ICP >4 hrs after admission**	**ICP w/in 4 hrs**	**Unadjusted RR (95% CI)**	**Adjusted RR (95% CI) Confounders**
Mortality	n=278	n=370		1.11 (0.83 - 1.48) GCS motor (GCSm)
	17.6%	23.5%	1.33 (0.99 - 1.8)	
Complication	n=98	n=370		0 .86 (0.68 - 1.08) ISS, age, GCSm, peds trauma hospital, peds ICU
	35.3%	31.9%	0.9 (0.71 - 1.15)	
Requires assistance at discharge *	n=224	n=278		1 (1- 1.01) ISS, age, gender, GCSm, systolic blood pressure (SBP), pulse, peds trauma hospital, peds ICU, head AIS
	71.9%	71.2%	0.99 (0.88-1.11)	
Total Hosp Length of Stay (Days)*	mean=26.3, SD 21.2	mean=21.7, SD 16	0.82 (0.72 - 0.95)	**0.84 (0.72- 0.97) ISS**
ICU Length of Stay (Days) *	mean=16.3, SD 13.9	mean=13.3, SD 10.9	0.82 (0.72 - 0.94)	**0.76 (0.66 - 0.86) ISS, age, pulse, GCSm**
Crani > 4 hrs compared to Crani placement within 4 hours in patients with TBI	Craniotomy >4 hrs	Craniotomy w/in 4 hrs		
Mortality	n=376	n=550		**1.98 (1.11 - 3.51) SBP, GCSm, Head AIS**
	3.46%	11.8%	3.42 (1.91 - 6.12)	
Complication	n=376	n=550		0 .83 (0.56 - 1.22) ISS, age, gender, SBP, Pulse, GCSm, mechanism of injury, peds trauma hospital, peds ICU, head AIS, abdominal AIS
	13.8%	13.6%	0.98 (0.69- 1.42)	
Requires assistance at discharge *	n=357	n=476		0.87 (0.68 - 1.12) ISS, age, SBP, pulse, GCSm, peds trauma hospital, peds ICU, head AIS, abdominal AIS
	25.8%	27.5%	1.07 (0.84 - 1.35)	
Total Hosp Length of Stay (Days)*	mean= 11.9, SD 15.2	mean= 9.3, SD 11.5	0.78 (0.66 - 0. 92)	**0 .69 (0.59 - 0.81) ISS, GCSm, abdominal AIS**
ICU Length of Stay (Days) *	mean=6.6, SD 10.2	mean 5, SD 7.6	0.77 (0.62 - 0.96)	**0.69 (0.57 - 0.83) ISS, GCSm, abdominal AIS, Head AIS**
Abd operation within 4 hours vs greater than 4 hours in patients with SOI **	Abd operation > 4 hours	Abd operation within 4 hours		
Mortality	n=142	n=274		3.10 (0.99 - 9.75) ISS, SBP, GCSm, mechanism, head AIS, abdominal AIS
	4.23%	16.42%	3.88 (1.74 - 8.68)	
Complication	n=142	n=274		0 .67 (0 .42 - 1.07) ISS, GCSm, mechanism, head AIS, abdominal AIS
	32.4%	19.3%	0.6 (0.41 - 0.6)	
Requires assistance at discharge *	n=129	n=221		0.87 (0.64 - 1.20) GCSm, mechanism, head AIS
	50.4%	24%	0.48 (0.36 - 0.64)	

ICP > 4 hrs compared to ICP placement within 4 hours in patients with TBI	**ICP >4 hrs after admission**	**ICP w/in 4 hrs**	**Unadjusted RR (95% CI)**	**Adjusted RR (95% CI) Confounders**
Total Hosp Length of Stay (Days)*	mean=23.2, SD 29.8	mean=10.9, SD 11.1	0.47 (0.39 - 0.57)	**0 .58 (0.47-0.73) ISS, GCSm, head AIS**
ICU Length of Stay (Days) *	mean=12.1, SD 11.9	mean 4.9, SD 7.2	0.4 (0.31 - 0.52)	**0.52 (0.37-0.74) ISS, GCSm, mechanism, head AIS**

*Those that died in the hospital excluded

**Those with bowel injury excluded