Impact of Trauma System Preparedness on the Outcomes of Severe Injuries Among Child Populations

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Abstract Severe child trauma poses a heavy burden upon the public's health and the nations' economies, in terms of mortality, morbidity, and disability. The burden varies by the maturity level of the adopted trauma system. This work aimed to identify the impact of trauma system maturity on the outcomes of care of severely injured children. Discharge data for the hospitalized trauma children in Florida (mature trauma system) and Indiana (immature trauma system) were retrospectively analyzed. All severely injured children, 1–15 years of age with an injury severity score ≥ 25 during 1999–2000 were included. Assessment involved the differences in specified treatment procedures, survival rates, hospital length of stay, and the need for post-hospital institutional care. Analysis revealed that Indiana children significantly stay longer in hospital, and that no differences in the rates of patient mortality, discharge-home, and selected procedures were found. Trauma system maturity impacts the volume and complexity of interventions, as well as the mortality, morbidity, and disability associated with severe children and adolescent trauma. The cost of such burden could be directed to improving the quality of the state's injury management services.

Keywords Immature trauma system · Injury severity score ≥ 25 · Mature trauma system · Pediatric trauma · Trauma outcomes

Introduction

Death, the gravest outcome of injury, represents a considerable fraction of severe childhood injury burden [1]. On the other hand, nonfatal injury was the leading cause of both temporary and permanent disability for patients 19 years and younger [2] and which accounted for a major proportion of health service utilization in children. The patterns of fatal childhood injury suggest that one-third of deaths are due to homicides in an urban setting; for example, house fires (34 %), firearms (19 %), and motor vehicle crashes (7 %) [3]. In the United States, the American College of Surgeons-Committee on Trauma (ACS-COT) has defined the resources for optimal care of trauma patients [4]. Pediatric trauma outcomes particularly involve the mechanism of injury, the pattern of tissue damage, prehospital triage, transport, and time lapse until professional treatment. Whether the trauma system is mandated, nonmandated, or voluntary evolving is the mainstay of trauma outcome. With a well-defined trauma triage policy, as in a mandated trauma system, high-risk patients are transported directly to a level I/II trauma center (TC) for specialized care, compared with transporting them to the nearest emergency department, as in the nonmandated system. The U.S. Congress had reestablished the Trauma Care Systems Planning and Development Act [5] (TCS-PDA) program within the services – Health Resources and Services Administration (HRSA) to aid in the assessment of current trauma systems. In one HRSA report, it was noted that there were inadequate data systems needed for evaluation in 30 of the 38 states, reporting some effort at trauma system development. While 37 of 50 states had some central reporting of trauma registry data from TCs, 22 of the 37 states with TC data do not collect NTC injury data [6]. Of the 1,154 general TCs, including 353 level I/II TCs in the United States [7], Florida has a mature trauma system that

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consists of 216 hospitals, 20 of which are level I/II TCs, as designated by the ACS. Indiana lacked such mandated triage policy; a key criterion for a mature trauma system. The state, instead, only encompassed out of 117 hospitals, seven level I/II TCs, three of which were taking serious steps toward eligibility for the ACS-TC consultation-verification program. The aim of this study, therefore, was to assess the differences in the outcomes of high-risk pediatric trauma, in terms of survival rates, hospital length of stay (HLOS), and proportion discharged home in a mandated trauma system (as Florida's) versus nonmandated system (as Indiana's). Particularly, discharge data from all hospitals in the two states would be analyzed.

Materials and Methods

The study used the same trauma discharge database described in a previous study by this investigator [8]. Subjects included all trauma children 1–15 years of age admitted in Florida and Indiana hospitals and TCs. The total number of subjects was 14,537 (11,059 Florida, 3,478 Indiana during 1999–2000). “Trauma cases” defined by the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9) diagnosis code 800.00 to 959.9 (“Injury” or “Poisoning”) [9] were admitted to the study. A maximum 10-diagnosis and 10-procedure ICD-9 codes were available in the database. Relevant hospital discharge data included demographic, diagnostic,

surgical procedures, mechanism of injury, and pattern of injury. Risk variables were as follows: 1) age 1–15 (frequently categorized as 1–5, 6–10, and 11–15); 2) sex; 3) pattern of injury (spleen, liver, pelvis, femur, spinal cord injury); 4) injury mechanism [motor vehicle accidents (MVA), falls, gunshot wounds (GSW), “other causes”, and “missing E-code” categories] [10]; 5) injury severity score (ISS), 1–75, split into four categories (1–8, 9–15, 16–24, and 25 or more to describe mild, moderate, mild severity, and severe injuries, respectively); 6) selected interventions (splenectomy, ventilation ≥ 4 days, tracheostomy); 7) hospital designation, according to trauma management capacity, either level I/II TC, or NTC. Unavailable data included the following: vital signs, the Glasgow coma scale (GCS), time elapsed between diagnosis and treatment, and the Glasgow outcome scale (GOS). While the principal outcome variable of interest was survival, equally important were other outcomes including the HLOS and post-discharge institutional care. The modified ISS measure [11] to categorize trauma severity was used in the study. Severely injured patients would frequently be tested as stratified by TC/NTC. Chi-square tests of independence with odds ratios (OR) and their 95 % confidence intervals (CIs) were performed for comparisons involving nominal or ordinal variables. Also, *t*-tests (or Mann Whitney *U* tests when normality distribution could be a concern) were used to compare the differences in the means of internal ratio scale variables. Our statistical analyses were conducted at the level of significance $\alpha=0.05$; *p* value <0.05 results were considered statistically significant.

Table 1 Pediatric trauma admissions in Florida and Indiana by age, ISS, and injury mechanism

State population	Florida		Indiana		OR	CI
	16 million		6.0 million			
	n	Rate per* 100,000/y	n	Rate per* 100,000/y		
All trauma admissions	11,059	34.5 ^a	3,478	29.0 ^b	1.18	0.60, 2.4
<i>Patients with ISS≥25</i>	(445)		(160)			
Male (ISS≥25)	298	67.0 %	101	63.0 %	1.30	0.65, 8.3
Mean age (± SD)y	9.7±4.45		8.9±4.99			
Age 1–5y (ISS≥25)	95/445	21.3 %	49/160	30.6 %	0.62	0.41, 0.92
Age 6–10y (ISS≥25)	123/445	27.6 %	39/160	24.4 %	1.19	0.87, 1.80
Age 11–15y (ISS≥25)	227/445	51.1 %	72/160	45.0 %	1.27	0.89, 1.90
MVA	220	49.4 %	49	30.6 %	2.20	1.50, 3.30
Fall	32	7.2 %	4	2.5 %	3.00	1.10, 8.70
GSW	10	2.2 %	3	1.9 %	1.20	0.33, 4.40
All other	54	12.2 %	34	21.2 %	0.51	0.32, 0.82
Total with E-code	316	71.0 %	90	56.2 %	1.90	1.80, 2.00
No E-code	129	29.0 %	70	44.0 %	0.53	0.36, 0.76

^a Rate per year: Florida=(11,059/16,000,000) X 100,000/2=34.5

^b Rate per year: Indiana=(3,478/6,000,000) X 100,000/2=29.0

Table 2 Selected procedures: patients with ISS $\geq$ 25 (All trauma settings combined)

	FLORIDA (<i>n</i> =445)		INDIANA (<i>n</i> =160)		OR	CI
Craniotomy	64 (14.4 %)		25 (15.7 %)		0.91	0.55, 1.50
ICP	136 (30.6 %)		46 (28.8 %)		1.10	0.73, 1.60
Abdominal surgery	59 (13.3 %)		22 (13.8 %)		0.96	0.57, 1.60
Splenectomy	41 (9.2 %)		9 (5.6 %)		1.70	0.81, 3.60
Splenic salvage	4 (1.0 %)		3 (2.0 %)		0.48	0.11, 2.10
Ventilator $\geq$ 4days	120 (27.0 %)		44 (27.55)		1.03	0.69, 1.54
Tracheostomy	30 (6.7 %)		5 (3.1 %)		2.24	0.85, 5.90
Bronchoscopy	15 (3.4 %)		5 (3.1 %)		1.08	0.39, 3.03
Swan-Ganz catheter	7 (1.6 %)		7 (4.4 %)		0.35	0.12, 1.00
Caval interruption	3 (0.7 %)		3 (3.0 %)		1.10	0.03, 53.0
	Trauma Center (TC)		Non-Trauma Center (TC)			
	FL (<i>n</i> =349)	IN (<i>n</i> =120)	FL (<i>n</i> =96)	IN (<i>n</i> =40)		
	%	%	%	%	OR	CI
Craniotomy	16.0 %	16.7 %	8.3 %	12.5 %	0.64	0.20, 2.079
ICP	33.5 %	32.5 %	19.8 %	17.5 %	0.16	0.45, 3.03
Abdominal surgery	11.2 %	10.0 %	20.8 %	25 %	0.79	0.33, 1.88
Splenectomy	7.0 %	1.7 %	17.7 %	17.5 %	1.02	0.40, 2.58
Splenic salvage	0.90 %	0.8 %	1.0 %	5.0 %	0.20	0.02, 2.20
Ventilator $\geq$ 4days	29.0 %	31.0 %	19.8 %	17.5 %	1.16	0.45, 3.03
Tracheostomy	7.0 %	2.5 %	6.3 %	5.0 %	1.27	0.25, 6.56
Bronchoscopy	4.0 %	3.3 %	1.0 %	2.5 %	0.41	0.03, 6.73
Swan-Ganz catheter	2.0 %	3.3 %	1.0 %	3.0 %	0.10	0.10, 54.00
Caval interruption	3.0 %	0.5 %	0.1 %	52. %	0.64	0.195, 2.08

NB. The number of performed procedures per patient may exceed that of the patients; some often needed >one procedure

Results

As shown in Table 1, the risk of admitting severe injuries in children 1–5 to all types of healthcare facilities was significantly lower in Florida (21.3 %) than in Indiana (30.6 %), (OR

0.62, CI 0.41, 0.92). The mean age, age groups proportions, and sex distribution could not be discriminated significantly in the two states. Florida significantly experienced higher rate of all-severity trauma admissions during the study period (34.5/1,00,000 vs. 29.0/1,00,000, OR 1.18, CI 0.60, 2.4). Notably,

Table 3 Distribution of ISS $\geq$ -patients by the selected outcome measures (unspecified by TCs and NTCs)

Outcome measures	Florida		Indiana		OR	CI	<i>p</i> -value
	n	%	n	%			
Crude MR ^a	(121/445)	27.2 %	(49/160)	30.6 %	0.846	0.57, 1.26	
MR 1–5 years	(37/95)	39.0 %	(20/49)	41.0 %	0.925	0.46, 1.87	
MR 6–10 years	(33/123)	27.0 %	(10/39)	26.0 %	1.060	0.47, 2.41	
MR 11–15 years	(51/227)	22.5 %	(19/72)	26.4 %	0.808	0.44, 1.44	
Mean HLOS ($\pm$ SD) ^a	10.8 $\pm$ 13.09		15.34 $\pm$ 23.6				0.021
Mean HLOS 1–5y	7.76 $\pm$ 8.32		13.37 $\pm$ 21.7				0.085
Mean HLOS 6–10y	0.33 $\pm$ 12.90		17.08 $\pm$ 21.8				0.073
Mean HLOS 11–15y	2.30 $\pm$ 14.50		15.74 $\pm$ 25.8				0.284
Discharge home ^a	(196/445)	44.0 %	(75/160)	47.0 %	0.892	0.62, 1.28	
Discharge home 1–5 y	(43/95)	45.0 %	(20/49)	41.0 %	1.199	0.60, 2.41	
Discharge home 6–10y	(57/123)	46.0 %	(21/39)	54.0 %	0.567	0.20, 1.22	
Discharge home 11–5y	(96/227)	42.3 %	(34/72)	47.0 %	0.819	0.48, 1.40	

^a Reference category: total with ISS $\geq$ 25 (dead+alive) per cause of injury per state (Table 1: patients with ISS $\geq$ 25, all care levels)

Table 4 Mortality rates, discharge home, hospital length of stay (ISS $\geq$ 25 Cases), by TCs & NTCs

Outcome measures	TC Admission				NTC Admission			
	FL n (%)	IN n (%)	OR	CI	FL n (%)	IN n (%)	OR	CI
Crude MR	103/349 (29.5 %)	40/120 (33.3 %)	0.84	0.54, 1.31	18/96 (18.8 %)	9/40 (22.5 %)	0.95	0.32, 1.66
MR 1–5y	29/71 (41.0 %)	18/434 (2.0 %)	0.96	0.45, 2.07	8/24 (33.3 %)	2/6 (33.3 %)	1.00	0.15, 6.70
MR 6–10y	27/97 (28.0 %)	9/30 (30.0 %)	0.90	0.37, 2.21	6/26 (23.0 %)	1/9 (11.1 %)	2.4	0.25, 23.2
MR 11–15y	47/181 (26.0 %)	13/472 (7.7 %)	0.92	0.45, 1.89	4/46 (8.7 %)	6/25 (24.0 %)	0.30	0.08, 1.92
Discharge home (Total)	138/349 (39.5 %)	55/120 (46.0 %)	0.77	0.51, 1.17	58/96 (60.45)	20/40 (50.0 %)	1.53	0.73, 3.21
Discharge home 1–5y	32/71 (45.0 %)	20/43 (37.7 %)	1.06	0.50, 2.27	11/24 (46.0 %)	0/6 (0.0 %)	1.40	0.00
Discharge home 6–10y	42/97 (43.3 %)	15/30 (50.0 %)	0.76	0.34, 1.74	15/26 (58.0 %)	6/9 (67.0 %)	0.68	0.14, 3.34
Discharge home 11–15y	35.4 % 64/181	20/47 (42.6 %)	0.74	0.38, 1.42	32/46 (70.0 %)	14/25 (56.0 %)	1.80	0.66, 4.93
			<i>p Value</i>				<i>p Value</i>	
Mean HLOS ($\pm$ SD) days (total)	11.06 $\pm$ 12.7	18.07 $\pm$ 26.1	0.005		9.8 $\pm$ 14.6	7.2 $\pm$ 9.4	0.098	
Mean HLOS 1–5y	7.5 $\pm$ 7.3	14.3 $\pm$ 22.7	0.435		8.6 $\pm$ 11.0	7.0 $\pm$ 10.4	0.462	
Mean HLOS 6–10y	10.7 $\pm$ 12.3	20.7 $\pm$ 23.6	0.050		8.8 $\pm$ 15.4	5.0 $\pm$ 3.8	0.664	
Mean HLOS 11–15y	12.7 $\pm$ 19.9	20.0 $\pm$ 30.4	0.518		1.9 $\pm$ 16.0	8.0 $\pm$ 10.7	0.124	

Computation of MR: Based on the following totals

Florida and Indiana patients (all ages) admitted to trauma centers, with ISS $\geq$ 25=349 and 120, respectively

Florida and Indiana patients (all ages) admitted to non-trauma centers, with ISS $\geq$ 25=96 and 40, respectively

Computation of Discharge Home%: Based on the following totals

Florida and Indiana patients (all ages) admitted to trauma centers, with ISS $\geq$ 25=349 and 120, respectively

MVA among ISS $\geq$ 25 patients was the most predominant injury mechanism in either state (49.4 % Florida, 30.6 % Indiana, being significantly higher in Florida; OR 2.20, CI 1.5, 3.3). Likewise, the frequencies of all injury mechanisms among ISS $\geq$ 25 children, other than GSW, significantly differed. Florida had almost triple severe fall injury proportion as in Indiana (7.2 % vs. 2.5 %, OR 3.0, 1.1, 8.7). Otherwise, Florida's "all other" mechanisms, including those with no E-code, were less frequent compared with Indiana's (12 % vs. 21 %, OR 0.51, CI 0.32, 0.82, and 29 % vs. 44 %, OR 1.9, CI 1.8, 2.0, respectively) (Table 1). Among the surgical procedures studied, only splenectomy was being significantly

performed more frequently in TCs in Florida (OR 4.35, CI 1.1, 18.7) (Table 2). Otherwise, no significant differences between the two states in the prevalence of other procedures were observed. On the other hand, Indiana's risky patients, unstratified, stay longer in hospital compared with Florida peers (mean HLOS 15.3 $\pm$ 23.6 days vs. 10.8 $\pm$ 13.09 days, $P=0.021$, respectively), (Table 3). Stratified by TC/NTC, Indiana risky patients stay at TC as long as 18.07 $\pm$ 26.1 days, compared with Florida counterparts who stay 11.06 $\pm$ 12.7 days, on average ($P=0.005$) (Table 4). Moreover, Indiana TC risky patients 6–10 stay almost double the duration of Florida counterparts (20.7 $\pm$ 23.6 days vs. 10.7 $\pm$ 12.7 days, $p=0.005$) (Table 4).

Table 5 Coding omissions, ten-diagnoses, and ten-procedures among ISS $\geq$ 25 patients, all trauma settings

Patient category	Florida		Indiana		OR	CI
	#	%	#	%		
Missing E-code (ISS $\geq$ 25 all ages) ^a	129/445	29.0 %	70/160	43.8 %	0.53	0.36, 0.76
Missing E-code 1–5y	29/95	30.5 %	18/49	36.7 %	0.72	0.35, 1.50
Missing E-code 6–10y	31/123	25.2 %	18/39	46.2 %	0.39	0.19, 0.83
Missing E-code 11–15y	70/227	31.0 %	34/72	74.0 %	0.50	0.29, 0.83
Patients 10-diagnoses	136/445	30.6 %	45/160	28.1 %	1.13	0.75, 1.68
Missing E-code, with 10-diagnoses	69/445	15.5 %	13/160	8.1 %	2.07	1.10, 3.86
With 10-procedures	67/445	15.1 %	18/160	11.3 %	1.4	0.83, 2.44

^a All other patients with ISS $\leq$ 25 and missing an E-code:

Florida: 1,567/10,614=14.8% vs. Indiana: 1,048/3,318=32.0%. OR=0.375, 95% CI 0.343, 411 ($p<0.001$)

Table 6 Coding omissions, 10-diagnoses, and 10-procedures among ISS $\geq$ 25 patients by TC/NTC

Patient category	Trauma center (C)				Non-Trauma Center (NTC)			
	Florida (349)	Indiana (120)	OR	CI	Florida (96)	Indiana (40)	OR	CI
Missing E-code (Total)	99/349 (28.4 %)	48/120 (40.0 %)	0.60	0.39, 0.92	30/96 (31.3 %)	22/40 (55.0 %)	0.37	0.17, 0.79
Missing E-code 1–5y	17/71 (23.0 %)	15/43 (34.9 %)	0.59	0.26, 1.35	11/24 (4.8 %)	3/6 (50.0 %)	0.85	0.14, 5.07
Missing E-code 6–10y	24/97 (24.7 %)	14/30 (46.7 %)	0.38	0.16, 0.88	12/46 (6.1 %)	15/26 (57.7 %)	0.44	0.09, 2.11
Missing E-code 11–15y	58/181 (32.0 %)	19/47 (40.0 %)	0.69	0.36, 1.35	12/96 (12.5 %)	2/40 (29.4 %)	0.26	0.09, 0.72
10-diagnoses	34.0 %	33.3 %	1.02	0.66, 1.59	(18.8 %)	(12.5 %)	1.62	0.56, 4.70
10-diagnoses with no E-code	16.3 %	9.2 %	1.93	0.98, 3.83	(12.5 %)	29.4 %	0.37	0.08, 1.73
10-procedures	18.6 %	12.5 %	1.60	0.88, 2.9	2.1 %	7.5 %	0.27	0.04, 1.64

From the data completion standpoint (Table 5), Florida misses an E-code for ISS $\geq$ 25 children, unstratified by age, less frequently than Indiana, either unclassified by TC/NTC (29 % vs. 43.8, OR 0.53, CI 0.36, 0.76) or classified by TC/NTC (28 % vs. 40 %, OR 0.6, CI 0.39, 0.92; 31 % vs. 55 %, OR 0.37, CI 0.17, 0.79, respectively). The same trend applies for the age groups 6–10 years and 11–15 years, as well as those who had no E-code, but have the 10-diagnoses documented [(25.2 % vs. 46.2 %, OR 0.39, CI 0.19, 0.83); (31 % vs. 74 %, OR 0.5, CI 0.29, 0.83); and (15 % vs. 8.1 %, OR 2.07, CI 1.1, 3.9), respectively].

Also, 6–10-year-old TC children with ISS $\geq$ 25 show a similar trend, as well as the 11–15-year-old NTC children (24.7 % Florida vs. 46.7 %, Indiana, OR 0.38, CI 0.16, 0.88), (13 % vs. 29 %, OR 0.26, CI 0.09, 0.72) (Table 6). Likewise, the prevalence of missing an E-code among trauma children with an ISS $<$ 25 was consistently lower in Florida than in Indiana (1,567/10,614=15 % vs. 1,048/3,318=32 %, OR 0.38, CI 0.15, 0.41) (Table 5, footnote).

Discussion

The utilized administrative trauma data helped describe the outcomes of high-risk injury among this population stratum in the different settings of care and trauma system maturity. However, several important pieces of clinical information are not generally available in an administrative database that normally would be obtainable in a more refined trauma registry; for example, vital signs, the GCS score, the prehospital time lapse, and the GOS. There could be limitations in using HLO outcome variable, too. In some states, hospitals may be providing inpatient rehabilitation, part of the overall inpatient stay; others transfer them to skilled nursing facilities. The administrative database we used does not code hospital transfers. Another limitation comparing multistate trauma systems was the absence of E-codes, which may partly be due to the limited number of computer fields

available to list the diagnoses. In the Indiana's administrative database, 15 fields are available for diagnoses, compared with 10 fields in the Florida's. Indiana recording system has been significantly missing E-codes more frequently than Florida. This trend has also been observed between the oldest two age groups (6–10 years, and 11–15 years). Analysis also indicates that E-code underreporting in less risky traumatized children (ISS $<$ 25) in Indiana accounts to 32 % versus only 15 % in Florida (Table 5). Indiana's E-code missing leads to bias and impacts the epidemiologic value of trauma data; for example, comparing the mechanisms of injury between states. It also impacts monitoring the efficiency of injury prevention programs, and has a negative influence on the precision in predictability of measuring the outcome.

Outcome analysis using the same dataset did not distinct the risk of mortality between the states' severely injured children. The likely "under-representativeness" of trauma-related mortality events due to missing "late mortalities"; for example, when trauma patients transferred elsewhere have passed away, may contribute to equivocal mortality data. In either situation, injured patients hospitalized at level I TCs are at lower risk of death after the trauma system had been established [12]. The mean HLO for high-risk children in Indiana hospitals, either acute care hospital or TC, was longer, a finding that warrants further investigation to see if quality trauma care availability statewide was involved. Although splenectomy rate among TC risky patients, combined, in Indiana was higher than that in Florida, there was not a corresponding significant variation in the rate of splenectomy among the same patient populations either in TC or NTC. This finding reflects the positive impact of the evolving trend of advocating a conservative management rather than splenectomy in cases of blunt splenic trauma. As of 2005, there were no universally accepted norms that can be used to assess state trauma systems by listing the optimal and achievable distribution of high-risk patients that should be treated in level I/II trauma centers. Existing triage protocols alone do not guarantee compliance with triage

instructions [13]. Florida TCs receive up to 54 % of trauma children, but what is unknown is whether this proportion is the goal for all trauma patients. Interstate comparisons of evolving systems may help establish these norms. However, other means of assessment need to be conducted to support the establishment of mandated systems; for example, cost effectiveness analysis studies. Thereby, on the short run, retrospective trauma studies should provide valid reference for resource-limited states not only on the degree to which trauma systems save lives, but on the component of trauma system improvement that can most assist in achieving optimal cost-effective trauma care.

Conclusions and Recommendations

Embracing a mandated trauma system provides appropriate environment to maintain quality under an umbrella of a mature trauma system. At the time of this study, Indiana was among the states that did not have such system, the absence of which may probably have impacted the outcomes of childhood trauma in its severest forms. This study provides that high-risk children under Indiana's non-mandated trauma system had an equal opportunity of surviving severe injuries, although they stay longer in hospital. Despite the database limitations; for example, lacking some evaluative information, such as GCS score, the goal and objectives of this research have been accomplished. Using existing pediatric trauma administrative data, the analysis could describe the differences in the severe trauma outcome variables in the studied states. The current Indiana child trauma database may well be basis for more integrated data system when resources have been directed to help Indiana's trauma system reach maturity.

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