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The Effect of Trauma Center Care on Pediatric Injury Mortality in California, 1999–2011

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Abstract

Background—Trauma centers (TC) have been shown to decrease mortality in adults, but this has not been demonstrated at a population-level in *all* children. We hypothesized that seriously injured children would have increased survival in a TC vs. non-trauma center (nTC), but there would be no increased benefit from pediatric-designated vs. adult TC *care*.

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Methods—This was a retrospective study of the unmasked California Office of Statewide Health and Planning Department patient discharge database (1999–2011). International Classification of Disease, Ninth Revision (ICD-9) diagnostic codes indicating trauma were identified for children (0–18) and injury severity was calculated from ICD-9 codes using validated algorithms. To adjust for hospital case mix, we selected patients with ICD-9 codes that were capable of causing death, and which appeared at both TCs and nTCs. Instrumental variable analysis using differential distance between the child’s residence to a trauma center and to the nearest hospital was applied to further adjust for unobservable differences in TC and nTC populations. IV regression models analyzed the association between mortality and TC vs. nTC care, as well as for pediatric vs. adult TC designations, adjusting for demographic and clinical variables.

Results—Unadjusted mortality for the entire population of children with nontrivial trauma (n=445,236) was 1.2%. In the final study population (n=77,874), mortality was 5.3%; 3.8% in nTCs and 6.1% in TCs. IV regression analysis demonstrated a 0.79 percentage point (95% CI –0.80 to –0.30; p=.044) decrease in mortality for children cared for in TC vs. nTC. No decrease in mortality was demonstrated for children cared for in pediatric vs. adult TCs.

Conclusion—Our IV TC outcome models use improved injury severity and case mix adjustment to demonstrate decreased mortality for seriously injured California children treated in TCs. These results can be used to take evidence-based steps to decrease disparities in pediatric access to, and subsequent outcomes for, trauma care.

Level of Evidence—Level III Therapeutic/Care Management.

Keywords

Injury outcome; Pediatric trauma; Designated trauma centers; Trauma systems; Injury mortality; Instrumental variable analysis

Background

Trauma is a leading cause of morbidity and mortality in the United States and the number one cause of mortality in young people.¹ Regionalized trauma systems have potential to improve the quality and outcomes of trauma care by organizing and coordinating all aspects of emergency care, and by assuring that seriously injured patients have access to the appropriate level of care.² Outcomes attributable to the trauma system as a whole are difficult to measure, as the trauma system includes: Emergency medical system (EMS) dispatch, initial assessment, stabilization and transport from the field to a hospital emergency department (ED); transfer to a higher level of care when required; definitive treatment in a trauma center (TC); as well as continuing services such as rehabilitation and preventative public health measures. However, one component of the trauma system, specialized trauma center care, has been demonstrated to decrease injury mortality in adults.³

The exact benefits of TC care for children *of all ages*, however, has not been definitively demonstrated at a population level. Children have different patterns of injury than adults as well as unique treatment, expertise and equipment requirements. All “adult” TCs (aTCs) are equipped to resuscitate and stabilize children with serious trauma, but pediatric trauma

centers (pTC) exist to provide further subspecialty care. Ultimately, however, both aTCs and pTCs are non-uniformly concentrated in urban areas, and pTCs are few in number. Because of these factors, we believe that pediatric trauma care outcomes rely more on the success of the trauma system as a whole than do adult outcomes. However, there are also low absolute numbers of severe injuries and deaths in children compared with adults, making outcome measures based on mortality challenging. In addition, the multiple players involved in this system, and the lack of a uniform data source accounting for the different arenas of care, render the benefit of trauma center care difficult to demonstrate for the *entire* pediatric population.

Our objective was to utilize a population-based, statewide administrative data source to assess the treatment effect (decreased mortality) for children cared for in designated TCs compared to non-trauma centers (nTCs); and to secondarily assess the treatment effect of subspecialty pTC care compared to aTC care. We hypothesized that seriously injured children would have decreased mortality in a TC vs. nTC but that this decreased mortality would not be apparent in pTCs compared to aTCs.

Methods

Study Design and Data

We conducted a retrospective cohort study of the unmasked California Office of Statewide Health Planning and Development (OSHPD) patient discharge data (PDD) from 1999–2011. All California licensed hospitals are required to submit discharge records biannually to OSHPD with demographic, diagnostic and financial variables for each patient.⁴ One primary diagnosis and up to 24 additional ICD-9 diagnostic codes are listed for each patient. Procedures performed, disposition (including length of stay and expected source of payment) are reported. The administrative panel on human subjects at our university, and the California Health Board approved this protocol.

Study Setting

California is a large and diverse state, home to 1/8 of the pediatric population of the US.⁵ It does not have a statewide trauma system; instead, approximately 20 local emergency medical services associations (LEMSAs) operate with guidance from the California EMS authority. TCs are “designated” by the LEMSAs which are able, but not required, to use the American College of Surgeons to verify the hospital’s qualifications as a TC. In 2008, California had 36 level I and II TCs, and 10 pTCs.⁶ Trauma centers are classified as aTC level I and II, III and IV and pediatric level I and II. Level III and IV TCs are generally smaller facilities that can provide advanced trauma support but cannot provide all the resources of a level I or II TC, so they must transfer seriously injured patients.

Study population

Using previously published methods,⁷ we queried the OSHPD-PDD for California residents 0 through 18 years of age, with nonscheduled admission to California acute care hospitals, with acute trauma diagnoses in the principal or any of the secondary ICD-9 diagnosis codes (800 to 904.9, 910 to 929.9 and 950 to 959.9) during the study period. We excluded children

with sole ICD-9 codes indicating minor injuries such as sprains and strains (840–848.9), open wounds (871.9–894.1), superficial abrasions (910.0–919.8), contusion with intact skin surface (920–924.9), foreign bodies (930–939), late effects of injury (905–909) and those with trauma ICD-9 codes associated with pregnancy and perinatal conditions. We also excluded children with the sole diagnosis of burns (940–949), because in California burns are cared for at regional burn centers, which can be separate from trauma centers. Finally, to ensure that patients were hospitalized for acute trauma, we excluded patients with no E-codes.⁸ Because these exclusions were not mutually exclusive, our preliminary study sample included 445,236 children with an overall mortality rate of 1.2%.

While rural areas stand to benefit the most from regionalization of trauma expertise and resources, the trauma *response* is most varied in these areas. We thus *initially* excluded patients who lived in rural areas and who lived >50 miles from a TC.⁹ Similarly, although patients receiving appropriate transfer to a higher level of care can illustrate the degree of pediatric regionalization achieved, these patients experience variable care within variable time frames and thus were also excluded from our major analyses. (*As part of our sensitivity analyses, we re-incorporated these patients into the study population with no major change in outcome. See Appendix 4 for further information.*)

Because the majority of injuries in children do not result in death, we further refined our study population to include only conditions that carried a risk of death in order to best evaluate both centers with the outcome variable of mortality. We identified ICD-9 code groupings accepted in the literature as indicative of serious injury with an increased likelihood of fatality including: fractures (of the skull, neck and trunk) intracranial injury and spinal cord injuries (800–809, 850–854, and 952); internal injury of the thorax, abdomen or pelvis (860–869); and injury of blood vessels (900–904).¹⁰ The emergency physician author (NEW), further identified and removed any injury codes which could be associated with, but not cause, death. If an injury's level of association with death was unclear, the author consulted with trauma colleagues. (See Appendix 1 for more detail)

Greater overall acuity coupled with disproportionate representation of complicated injuries in a TC can confound comparisons of mortality between TC and nTC. Trauma designated hospitals have more experience coding injuries in an administrative database resulting in more refined or rare diagnoses coded uniquely in a TC. Thus we further restricted our population to include only diagnoses that occurred in both TC and nTC populations. Our final sample included 77,874 seriously injured children, who were all seen at either nTCs or Level I/II TCs.

Variables

Outcome variable—In-hospital mortality

Treatment variable—TC designation

Independent variables—Demographic variables included: sex, age, race/ethnicity, and insurance status. We derived zip-code level median household income categories for patient resident zip-code¹¹ which we then correlated with the 2004 federal poverty designation

level of \$18,850 for a family of 4.¹² Distance from the patient residence to the hospital was calculated by the method of Phibbs and Luft¹³ as the shortest distance between the centroids of the patient's residence and the hospital's zip-codes.¹⁴

We included external cause of injury codes (E-codes), since injury outcome is associated with the injury mechanism and intent. We calculated injury severity from ICD-9 diagnostic codes using validated injury severity scoring systems (ICDPIC Stata v. 11, StataCorp, College Station, TX).¹⁵⁻¹⁸ Although the Injury Severity Score (ISS) is the most commonly used scoring system, it is expert consensus based, and uses a non-linear, discontinuous scale. The Trauma Mortality Prediction Model (TMPM) is a newer mortality prediction model. It uses ICD-9 CM injury codes to generate empirically derived survival risk ratios and develops a measure of injury severity based on regression modeling.¹⁹ We used TMPM as the primary injury severity scoring system for our primary analyses but performed sensitivity analyses with ISS (Appendix 3). Trauma centers were identified from the California EMSA website.⁶

Data analysis

Our analyses tested the association between mortality and TC designation. In our primary analyses, we compared outcomes from nTCs with level I and II TCs, regardless of pediatric designation. In our secondary analysis, we compared outcomes from adult level I and II TCs with pTCs. TCs classified as both adult and pediatric were identified as TCs in the primary analyses and as pTCs in the secondary analyses.

Regression analysis is a method classically used to estimate the relative contribution of different variables to an outcome of interest. In many cases, this method is sufficient to adjust for observable differences in patient populations. However, differences in patients may be un-observable and the effect of the treatment will be confounded. In the case of trauma, clinicians are well aware that patients cared for in TCs are different in many characteristics from those cared for in nTCs. These differences are not fully reflected by available variables including diagnoses or injury severity scores derived from administrative data.

Randomized control trials (RCT) are the ideal method to evaluate outcomes when unobservable variables are possible confounders. They insure that patients receiving a treatment are similar to those that are not. However in many cases, such as in the case of TC care, an RCT is not possible and in these cases an Instrumental Variable method can be utilized to achieve a "pseudorandomization" of observational data. The instrumental variable approach identifies a variable, the "instrumental variable," which correlates with the treatment variable but does not have an effect on the outcome. The instrumental variable provides a way of randomly assigning people to a treatment or control group (analogous to a coin toss) based on a factor that is associated with the patient's treatment but is not directly associated with the outcome.²⁰ Distance has been used as an instrumental variable in classic studies assessing outcome of specialty hospitals for acute myocardial infarction,²⁰ as well as trauma.^{10,21}

In this study, our IV is the differential distance (DD) between the nearest acute care hospital and the nearest TC. DD meets the two key criteria of an instrumental variable: it is highly correlated with the treatment received but does not directly affect outcomes. (See Appendix 2 for instrumental variable analysis details and diagnostics.)

Our model estimated instrumental variable adjusted mortality differences using DD from a trauma center as the IV. In all models, we adjusted for all covariates including: age categories, gender, race/ethnicity, median household income of zipcode (in terciles), insurance status, injury severity (TMPM grouped in quartiles), E-code, injury category and year. (*In sensitivity analyses we included two important populations which were initially excluded: rural and transfer patients. See Appendix 4 for more detail.*)

All variables were checked to confirm a normal distribution (parametric), linearity of continuous variables and additivity of effects, as required by the assumptions of the regression model. In addition, model assumptions were verified, including functional form, random distribution of residuals, and for outliers or influential points. P values less than .05 were apriori designated as statistically significant. Statistical analysis was performed using SAS 9.3 (SAS Institute Inc, Cary, NC) and STATA 10.1 for Windows (StataCorp LP, College Station, TX).

Results

Our final study population contained 77,874 seriously injured children: 52,214 (67.1%) were cared for in a TC (Table 1). Approximately half of the children were older adolescents (39,263); almost three quarters were male (56,664). The majority of injuries were unintentional. The top two injury mechanisms were motor vehicle crash (29,986), and falls (12,999). A total of 4,146 (5.3%) of the children in our sample died. TCs cared for more than double the volume of trauma patients of nTCs (n=52,214 vs. 25,660 respectively). Race/ethnicity and socioeconomic profiles were different between TCs and nTCs. In general, an increased proportion of injured children cared for in a TC were Black or Hispanic and from poorer households than those in nTCs. It is notable that Blacks comprised 13.5% of the TC population, but 6.7% of the California population. Asians comprised approximately 5–6% of the TC and nTC population although they make up 10.9% of the California population.²² TCs cared for a larger proportion of children with public insurance than nTCs (53.1 vs. 34.1%). Fewer mild injuries were cared for in TCs compared to nTCs (31.0 vs. 41.3%); in contrast TCs cared for proportionally more severely injured patients (31.2 vs. 23.8%). A little less than double the proportion of children died in a TC vs. nTC (6.1 vs 3.8%). Of children cared for within a TC (52,214), approximately three quarters (38,836) were cared for in an aTC and one quarter were cared for in pediatric-specific trauma centers. Children cared for in an aTC vs. pTC were older (61.9 vs. 27.2% were 15–19 years of age) and a smaller proportion had public insurance (49.7 vs. 58.9%, respectively). Of children cared in an aTC and pTC, 6.3 vs. 5.8% respectively, died. (Table 1).

Our model demonstrates the effect of TC vs. nTC care on the population of children with serious injury who could benefit from trauma center care (n=77,874 with an unadjusted mortality of 5.3%) (Table 2). Using IV techniques to adjust for unobservable differences in

the populations cared for in TC vs. nTC, we demonstrate a -0.79 (95% CI -0.80 to -0.30 ; $p=0.044$) percentage point impact on mortality for children cared for in TC vs. nTC.

Sensitivity analyses which included the a) rural, b) transfer and c) rural and transfer populations combined into our analyses demonstrate: a -0.71 (95% CI -1.22 to 0.03 ; $p=0.53$); a -0.98 (95% CI -1.78 to -0.22 ; $p=0.012$); and a -0.95 (95% CI -1.70 to -0.21 ; $p=0.012$) percentage point impact on mortality in TC vs. nTC (see Appendix 4 table A-4b for details).

Our model demonstrates that of children with serious injury, payer status had a significant impact on mortality in both models. The categories of “self-pay” and “other payer” are associated with a 3.13 (95% CI 2.64 to 3.64 ; $p<0.0001$) and 2.05 (95% CI 1.16 to 2.95 ; $p<0.0001$) percentage point increase in mortality, respectively. Higher household income categories are associated with a statistically significant decrease in mortality. Households with income between 2–3 times and greater than 3 times the federal poverty level had -0.39 (95% CI -0.69 to -0.09 ; $p=0.009$) and -0.44 (95% CI -0.78 to -0.10 ; $p=0.01$) percentage point decrease in mortality, respectively. Race/ethnicity categories were not associated with a clear pattern of mortality benefit. Mechanisms of intentional injury had no mortality benefit from TC care and in fact there was a 12.53 (95% CI 11.06 to 14.00 ; $p<0.0001$) percentage point increase in mortality. However, assault injuries had a significant mortality benefit of a -1.14 (95% CI -1.70 to -0.59 ; $p<0.0001$) percentage point decrease in mortality from TC care. (Table 2)

Our second model analyzed the effect of aTC vs. pTC care on the population of children with serious injury who could benefit from trauma center care ($n=52,214$ with an unadjusted mortality of 6.5%). We found a 0.64 (95% CI -0.26 to 1.54 ; $p=0.16$) percentage point increase in mortality for children treated in an pTC vs. aTC, which was not statistically significant. (Table 3)

Discussion

Seriously injured children have unique resource and expertise needs, which are not uniformly available. There has been, to date, insufficient evidence to determine the optimal location of care for children with trauma.²³ Most outcome studies are from single institutions and are unable to account for regionalization of trauma services. To our knowledge, there are very few population-wide studies measuring the benefit of TC compared with nTC care for children.²⁴ While Rutledge did not find decreased mortality for children with a trauma center within the county of injury in North Carolina,²⁵ Hulka demonstrated decreased pediatric mortality from trauma in the Oregon statewide trauma system.²⁶ More recently, Pracht demonstrated decreased mortality in children (0–19 years) receiving TC care in Florida.¹⁰ We demonstrate that, in California, seriously injured children cared for in TCs have decreased mortality compared to children cared for in non-trauma hospital settings. Our sensitivity analyses support the strength of our models, demonstrating that the TC mortality benefit extends to rural and transfer patients although the magnitude and overall significance of the effect varies.

Although not our primary outcome, we note with concern that after controlling for clinical and socio-demographic variables including median household income and race/ethnicity, children with “self pay” and “other payer” status had up to a 3 percentage point increase in death after trauma. This finding of increased rates of trauma death for children from poor households²⁷ and who are uninsured^{28,29} has been noted in the literature. Our previous work has also demonstrated that uninsured injured children have an increased likelihood of dying in the ED as compared to privately insured children.³⁰ Reasons for this disparity in outcomes have been postulated as possibly due to decreased utilization of medical care and preventative services, resulting in poorer baseline health and increased preexisting conditions, as well as decreased access to quality care after an injury.^{27,29,31}

Our sensitivity analyses, which included children living in rural areas and transfer patients, continue to demonstrate a mortality benefit for children cared for in a TC. Although these results must be interpreted with caution, they may provide evidence that current local EMS system practices are operating effectively for these challenging populations most in need of systematic trauma care.

Much of the discourse regarding whether trauma care improves outcomes for children has focused on whether pediatric specific trauma care has better outcomes than aTCs, with controversial results.^{32–34} In Florida, Pracht et al used a population-wide analysis similar to ours, and found no significant mortality benefit for pediatric specific trauma center care in younger children aged 0–15, but did find benefit when all children (0–19) were included in the model. We were unable to replicate those results. *However, given the relatively low overall mortality rate of pediatric trauma, the fact that pTCs are scarce and non-uniformly distributed, in conjunction with other confounders including differences in demographic, geographic and trauma system characteristics between Florida and California, we were not surprised that we were unable to demonstrate that subspecialty pTC care has any mortality benefit over aTC care in California.*

Regardless of our ability to demonstrate a mortality difference in pTC vs. aTC outcomes for children with serious injury; we believe that pediatric subspecialty care has many benefits, including possible mortality benefits not demonstrable with our analytic methods. However, ultimately a minority of injured children in the US are cared for in pTCs³⁵ or children’s hospitals.³⁶ We believe that the discourse regarding whether trauma care improves outcomes for children must focus on our finding that trauma specific care, be it adult or pediatric, improves patient outcomes. Our research and previously published literature clearly mandate that we must act now to ensure every child has access to specialized trauma care, with further access to subspecialty care an important future step.^{3,10,32,33}

This is one of the largest population-based analyses of which we are aware, which demonstrates that TC care saves lives for seriously injured children. Given that pediatric trauma care outcomes are dependent on regionalization of services, of which TC care is only one component, and because we use administrative data, we suspect our results are actually an underestimation of the benefits of TC and trauma system care. However, we believe our findings and methodology are significant initial steps to enable academicians, physicians, EMS administrators and policymakers to take evidence-based steps to decrease disparities in

access to and outcomes of trauma care for children.³⁷ For example, based on our results, as well as suggested by others, EMS and community should be educated to initially bring seriously injured children to a TC regardless of pediatric subspecialty status.³² Although further research is necessary to discover how these findings might be applied to rural and transfer populations, these data might support systematic development of formal transfer agreements between nTC and TC. Our methods can be used to further understand if outcomes are improved if subpopulations of critical trauma patients are transported directly to a trauma center (bypassing closer, local facilities), as has been demonstrated for closed head injury in adults.³⁸

Our work has limitations. While California is a large and diverse state, our analyses represent only one state. Although it is a common belief among trauma researchers that physiologic data is needed to demonstrate trauma care outcome benefits, we use administrative hospital discharge data, as it was the only way to conduct a total population analysis without a statewide trauma system. We also stringently defined our population of seriously injured children as children with injuries that could result in death. Using physiologic data as well as data linked across different arenas of care (out-of-hospital, ED, and in-hospital) are the next steps in understanding the full scope of trauma center outcomes. Additionally, mortality may be too crude of an outcome measurement and alternative outcomes to survival such as processes of care,³⁹ measures of functional outcomes, and quality of care are needed to fully demonstrate improved trauma center outcomes.

Conclusion

Our trauma center outcome models use improved injury severity and case mix adjustment, as well as unique statistical methods to demonstrate decreased mortality for seriously injured children treated in major trauma centers.

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Appendix 1

Method used to limit the study population to children with serious injury potentially associated with death.

We identified ICD-9 code groupings accepted in the literature as indicative of serious injury with a high likelihood of fatality including: fractures (of the skull, neck and trunk) intracranial injury and spinal cord injuries (800–809,850–854, and 952); internal injury of the thorax, abdomen or pelvis (860–869); and injury of blood vessels (900–904).¹⁰

To further refine our population, the emergency physician author (NEW) identified and removed any injury codes which could be associated with, but not cause, death. If an injury's level of association with death was unclear, the author consulted with trauma colleagues.

Our study population thus included patients that had the following ICD-9 diagnostic codes included anywhere in the primary and up to additional 24 ICD-9 diagnostic codes possible.

Table A-1

ICD-9 codes indicative of serious, potentially fatal, injury

Injury Category	ICD-9 codes (Specific)
Fracture of Skull (800–804)	800.05, 800.06, 801.05, 801.06, 801.15, 801.16, 801.2x, 801.3x, 801.45, 801.46, 801.55, 801.56, 801.65, 801.66, 801.7x, 801.8x, 801.9x, 803.05, 803.06, 803.15, 803.16, 803.2x, 803.3x, 803.45, 803.46, 803.55, 803.56, 803.65, 803.66, 803.7x, 803.8x, 803.9x, 804.05, 804.06, 804.15, 804.16, 804.2x, 804.3x, 804.4x, 804.55, 804.56, 804.65, 804.66, 804.7x
Fracture of Spine and Trunk (805–809)	805.0x, 805.1x, 807.03, 807.04, 807.05, 807.06, 807.07, 807.08, 807.09, 807.1x, 807.4, 807.5x, 807.6x, 808.x
Dislocation-multiple locations (839)	839.0x, 839.1x
Intracranial Injury, Excluding those with skull fracture (850–854)	850.4, 851.05, 851.06, 851.1x, 851.2x, 851.3x, 851.4x, 851.5x, 851.6x, 851.7x, 851.8x, 851.9x, 852.x, 853.x, 854.x
Internal injury of chest, abdomen and pelvis (860–869)	All
Open wound of neck and chest (874, 875)	874.0x, 874.0x, 874.1x, 874.4x, 874.5x, 875.x
Injury to blood vessels (900–904)	900.x, 901.x, 902.x, 904.0, 904.2,
Crushing injury of face, scalp, neck and trunk (925, 926)	925.2, 926
Injury to nerves and spinal cord	952.0x, 952.1x, 958.0, 958.1, 958.2, 958.4, 958.5

Appendix 2

Details of Instrumental Variables analysis

Distance has been used as an IV in classic studies assessing outcome of specialty hospitals for acute myocardial infarction,²⁰ as well as trauma.^{10,21} Thus, we used the differential distance (DD) between the nearest acute care hospital and the nearest TC as our IV. DD meets the two key criteria of an IV; it is highly correlated with the treatment received; however, DD does not directly affect outcomes.

A DD of ≤ 4 miles and >4 miles broke our population into two approximately equally sized groups. Gender, age groupings and injury severity were proportionally similar in both groups; race/ethnicity, insurance, household income and some injury characteristics varied (Table A-2).

Classic econometric studies have used a two step linear model with their IV analyses,^{20,41} although the majority of trauma outcome studies use a bivariable probit model.^{10,21,38} We estimated both types of models with similar trends but present the linear models because the results were much easier to interpret.

The partial F of the instrument is the definitive regression diagnostic for instrumental variables analyses. It is a test of the explanatory power of the instrument. The partial Fs of our instrument (stated at the bottom of each model) are well above the recommended value of 30 for a superior instrument.⁴⁰

Table A-2

Comparison of the populations with a DD of ≤ 4 miles and >4 miles.

	Total	Non-Trauma Center	%	Trauma Center (TC)	%	DD ≤ 4 mi	%	DD >4 mi	%
Total	77,874	25,660	32.95%	52,214	67.05%	37,936	52.60%	37,019	46.80%
Total TC									
Age (yr)									
0-364 days	3,877	1,455	5.67%	2,422	4.64%	1,997	5.26%	1,693	4.57%
1-4	9,410	2,765	10.78%	6,645	12.73%	4,947	13.04%	4,126	11.15%
5-9	10,373	3,492	13.61%	6,881	13.18%	5,074	13.38%	5,012	13.54%
10-14	14,951	5,521	21.52%	9,430	18.06%	6,898	18.18%	7,530	20.34%
15-19	39,263	12,427	48.43%	26,836	51.40%	19,020	50.14%	18,658	50.40%
Gender									
Male	56,664	18,898	73.65%	37,766	72.33%	27,842	73.39%	26,663	72.03%
Female	21,203	6,760	26.34%	14,443	27.66%	10,092	26.60%	10,352	27.96%
Unknown	7	2	0.01%	5	0.01%	2	0.01%	4	0.01%
Race/Ethnicity									
White-non Hispanic	28,765	12,047	46.95%	16,718	32.02%	10,865	28.64%	16,946	45.78%
Black-non Hispanic	8,936	1,906	7.43%	7,030	13.46%	6,055	15.96%	2,575	6.96%
Hispanic	32,125	9,429	36.75%	22,696	43.47%	16,734	44.11%	14,063	37.99%
Asian	4,474	1,372	5.35%	3,102	5.94%	2,565	6.76%	1,754	4.74%
Native American	184	69	0.27%	115	0.22%	66	0.17%	118	0.32%
Other/unknown	3,390	837	3.26%	2,553	4.89%	1,651	4.35%	1,563	4.22%
Payer									
Public	36,441	8,736	34.05%	27,705	53.06%	19,714	51.97%	15,117	40.84%
Hmo	11,738	6,179	24.08%	5,559	10.65%	5,396	14.22%	6,066	16.39%
Private	22,207	8,233	32.08%	13,974	26.76%	9,077	23.93%	12,318	33.27%
Self pay	6,053	2,227	8.68%	3,826	7.33%	2,957	7.79%	2,914	7.87%
Other/unknown	1,435	285	1.11%	1,150	2.20%	792	2.09%	604	1.63%
Income									
$\leq 2^*$ FPL	24,060	6,538	25.48%	17,522	33.56%	15,737	41.48%	7,568	20.44%
2^* FPL - 3^* FPL	29,567	10,069	39.24%	19,498	37.34%	11,818	31.15%	16,467	44.48%
$>3^*$ FPL	22,153	8,289	32.30%	13,864	26.55%	9,590	25.28%	11,764	31.78%
NA	2,094	764	2.98%	1,330	2.55%	791	2.09%	1,220	3.30%
Disposition									
Died	4,146	972	3.79%	3,174	6.08%	2,124	5.60%	1,879	5.08%
Discharge	73,726	24,687	96.21%	49,039	93.92%	35,812	94.40%	35,138	94.92%
Unknown	2	1	0.00%	1	0.00%	0	0.00%	2	0.01%
Injury Mechanism									
Fall	12,999	5,601	21.83%	7,398	14.17%	6,526	17.20%	5,962	16.11%
Firearm	9,543	2,077	8.09%	7,466	14.30%	6,107	16.10%	3,141	8.48%
MVA	29,986	7,344	28.62%	22,642	43.36%	13,871	36.56%	15,106	40.81%
Injury Type									
CNS	30,387	8,591	33.48%	21,796	41.74%	15,041	39.65%	14,230	38.44%
Abd thorax	39,419	13,449	52.41%	25,970	49.74%	18,503	48.77%	19,293	52.12%
blood vessels	2,410	470	1.83%	1,940	3.72%	1,411	3.72%	894	2.41%
Other	18,005	5,144	20.05%	12,861	24.63%	8,282	21.83%	8,898	24.04%

	Total	Non-Trauma Center	%	Trauma Center (TC)	%	DD<=4mi	%	DD>4mi	%
Total	77,874	25,660	32.95%	52,214	67.05%	37,936	52.60%	37,019	46.80%
Injury Severity									
Iss n/a	26,765	10,601	41.31%	16,164	30.96%	13,412	35.35%	12,669	34.22%
Mild (iss<9)*	28,623	8,905	34.70%	19,718	37.76%	13,997	36.90%	13,463	36.37%
Moderate (9<=iss<=15)	22,373	6,099	23.77%	16,274	31.17%	10,484	27.64%	10,829	29.25%
Severe (iss>15)	113	55	0.21%	58	0.11%	43	0.11%	58	0.16%

* ISS=Injury Severity Score

Appendix 3

Sensitivity analysis of regression analyses between nTC and TC using ISS as the injury severity score.

Table A-3

Regression model demonstrating treatment estimates of effect (decreased mortality) of pediatric trauma center care vs. adult trauma center care using ISS as the injury severity score.

All models have been adjusted for demographic and clinical variables as delineated in the text including: age, sex, race/ethnicity, median household income, payer status, injury severity (ISS) and mechanism, and year.

Population (n=52,214; unadjusted mortality: 6.5%)	Estimate*	(p)	CI
Pediatric Trauma Center vs. Adult Trauma Center Care			
Trauma center mortality effect	0.33	0.47	-0.56 to 1.21

Regression diagnostics: The partial F of 219.7 is well above the recommended value of 30 for a superior instrument.⁴⁰

* Estimates are in percentage points

Appendix 4

Sensitivity analysis of analyses including rural and transfer populations. We initially excluded rural and transfer populations from our analyses. After putting these patients back into the study population, we demonstrate the demographics of the entire population of seriously injured pediatric trauma patients after exclusions and adjustment for difference in TC and nTC hospital case mix. (Table A-4a).

We created models demonstrating estimates of treatment effect (decreased mortality) of trauma center care vs. non-trauma center care including the rural population (Table A-4b).

All models have been adjusted for demographic and clinical variables as delineated in the text including: age, sex, race/ethnicity, median household income, payer status, injury severity (TTPM) and mechanism, and year.

Table A-4a

Demographics of population of seriously injured pediatric trauma patients including rural and transfer populations, after exclusions and adjustment for difference in TC and nTC hospital case mix.

	Total	Non-Trauma Center	%	Trauma Center (TC)	%	Adult TC	%	Pediatric TC	%
Total	90,800	31,481	34.67%	59,319	65.33%	40,364	44.45%	18,258	20.11%
Total TC									
Age (yr)									
0-364 days	4,848	1,809	5.75%	3,039	5.12%	1,327	3.29%	1,552	8.50%
1-4	11,178	3,414	10.84%	7,764	13.09%	4,034	9.99%	3,605	19.74%
5-9	12,294	4,274	13.58%	8,020	13.52%	4,145	10.27%	3,757	20.58%
10-14	17,645	6,745	21.43%	10,900	18.38%	6,136	15.20%	4,675	25.61%
15-19	44,835	15,239	48.41%	29,596	49.89%	24,722	61.25%	4,669	25.57%
Gender									
Male	65,578	22,973	72.97%	42,605	71.82%	29,799	73.83%	12,271	67.21%
Female	25,215	8,506	27.02%	16,709	28.17%	10,562	26.17%	5,985	32.78%
Unknown	7	2	0.01%	5	0.01%	3	0.01%	2	0.01%
Race/Ethnicity									
White-non Hispanic	35,896	15,402	48.92%	20,494	34.55%	14,250	35.30%	6,002	32.87%
Black-non Hispanic	9,713	2,294	7.29%	7,419	12.51%	5,066	12.55%	2,254	12.35%
Hispanic	35,819	11,024	35.02%	24,795	41.80%	17,428	43.18%	7,087	38.82%
Asian	4,937	1,615	5.13%	3,322	5.60%	2,315	5.74%	963	5.27%
Native American	250	98	0.31%	152	0.26%	99	0.25%	53	0.29%
Other/unknown	4,185	1,048	3.33%	3,137	5.29%	1,206	2.99%	1,899	10.40%
Payer									
Public	41,584	10,529	33.45%	31,055	52.35%	20,027	49.62%	10,712	58.67%
HMO	14,325	8,020	25.48%	6,305	10.63%	4,137	10.25%	2,080	11.39%
Private	26,494	9,974	31.68%	16,520	27.85%	11,601	28.74%	4,680	25.63%
Self pay	6,799	2,604	8.27%	4,195	7.07%	3,493	8.65%	658	3.60%
Other/unknown	1,598	354	1.12%	1,244	2.10%	1,106	2.74%	128	0.70%
Income*									

	Total	Non-Trauma Center	%	Trauma Center (TC)	%	Adult TC	%	Pediatric TC	%
Total	90,800	31,481	34.67%	59,319	65.33%	40,364	44.45%	18,258	20.11%
<=2* FPL	27,983	8,198	26.04%	19,785	33.35%	13,877	34.38%	5,750	31.49%
2* FPL - 3* FPL	35,025	12,659	40.21%	22,366	37.70%	14,822	36.72%	7,280	39.87%
>3* FPL	25,156	9,577	30.42%	15,579	26.26%	10,459	25.91%	4,865	26.65%
Unknown	2,636	1,047	3.33%	1,589	2.68%	1,206	2.99%	363	1.99%
Disposition									
Died	4,836	1,201	3.81%	3,635	6.13%	2,528	6.26%	1,100	6.02%
Discharge	85,961	30,278	96.18%	55,683	93.87%	37,836	93.74%	17,157	93.97%
Unknown	3	2	0.01%	1	0.00%	0	0.00%	1	0.01%
Injury Mechanism**									
Fall	15,281	6,649	21.12%	8,632	14.55%	5,074	12.57%	3,240	17.75%
Firearm	10,251	2,419	7.68%	7,832	13.20%	6,453	15.99%	1,321	7.24%
MVA	35,282	9,536	30.29%	25,746	43.40%	17,647	43.72%	7,979	43.70%
Injury Type***									
Central nervous system	35,481	10,601	33.67%	24,880	41.94%	15,836	39.23%	7,760	42.50%
Abd thorax	45,583	16,314	51.82%	29,269	49.34%	20,177	49.99%	8,989	49.23%
Blood vessels	2,676	559	1.78%	2,117	3.57%	1,638	4.06%	476	2.61%
Other	21,632	6,659	21.15%	14,973	25.24%	9,383	23.25%	5,379	29.46%
Injury Severity									
Mild (iss<9)****	30,652	12,587	39.98%	18,065	30.45%	12,708	31.48%	5,276	28.90%
Moderate(9<=iss<=15)	33,022	10,902	34.63%	22,120	37.29%	15,503	38.41%	6,516	35.69%
Severe (iss>15)	26,982	7,922	25.16%	19,060	32.13%	12,128	30.05%	6,420	35.16%
Iss not listed	144	70	0.22%	74	0.12%	25	0.06%	46	0.25%
MSA status#									
Rural	6,714	3,065	9.74%	3,649	6.15%	2,308	5.72%	1,341	7.34%
Urban	84,086	28,416	90.26%	55,670	93.85%	38,056	94.28%	16,917	92.66%
Transfer status									
Transferred-in	6,246	2,692	8.55%	3,554	5.99%	1,393	3.45%	2,113	11.57%

Missing data was minimal. There was no differential missing data rate by outcomes

* Income is median household income per zipcode and is based on federal poverty level (FPL) from 2004 (\$18,850 household income)

** Injury Mechanism is based on E-code; Patients can have 0 to 5 E-codes thus the column sum can be greater than 100%. We list only the top three mechanisms of injury.

Injury type: Injury type is categorized according to ICD-9 groupings. We list only the most serious categories. These are not mutually exclusive.

ISS= Injury Severity Score

MSA=metropolitan statistical area as designated by U.S. Census Bureau

Table A-4b

IV Regression models demonstrating estimates of treatment effect (decreased mortality) of trauma center care vs. non-trauma center care including rural, transfer and both populations. We include also the estimates of age and payer status on treatment effect. All models have been adjusted for demographic and clinical variables as delineated in the text including: age, sex, race/ethnicity, median household income, payer status, injury severity (TPM) and mechanism, and year.

	Population of seriously injured children including rural population (n=80,795)			Population of seriously injured children including transfer population (n=80,219)			Population of seriously injured children including rural and transfer population (n=86,934)		
	Est. *	(p)	CI	Est.	(p)	CI	Est.	(p)	CI
TC mortality effect	-0.71	0.053	-1.22 to 0.03	-0.98	0.012	-1.78 to -0.22	-0.95	0.012	-1.70 to -0.21
Age									
0-1	ref			ref			ref		
1-4	1.28	0.001	0.54 to 2.02	1.13	0.002	0.41 to 1.84	1.12	0.002	0.43 to 1.81
5-9	0.84	0.03	0.08 to 1.59	0.56	0.13	-0.17 to 1.30	0.51	0.16	-0.20 to 1.22
10-14	0.29	0.44	-0.44 to 1.02	-0.04	0.91	-0.76 to 0.68	-0.05	0.88	-0.75 to 0.64
15-19	0.27	0.45	-0.44 to 0.98	0.01	0.98	-0.70 to 0.68	-0.1	0.77	-0.77 to 0.57
Gender									
Male	ref			ref			ref		
Female	-0.09	0.55	-0.39 to 0.21	-0.06	0.69	-0.36 to 0.24	-0.08	0.58	-0.37 to 0.21
Race/Ethnicity									
White non Hispanic	ref			ref			ref		
Black non Hispanic	0.36	0.14	-0.11 to 0.84	0.39	0.11	0.22 to 1.39	0.35	0.14	-0.11 to 0.81
Hispanic	0.07	0.69	-0.26 to 0.39	0.08	0.62	-0.24 to 0.41	0.06	0.60	-0.26 to 0.37
Asian	0.94	0.002	0.35 to 1.52	0.81	0.01	0.24 to 1.26	0.86	0.001	0.29 to 1.43
Native	-0.01	0.99	-2.50 to 2.48	0.46	0.73	-2.18 to 3.11	0.21	0.94	-2.18 to 2.60
Other	0.61	0.11	-0.13 to 1.35	1.02	0	0.26 to 1.77	0.65	0.02	-0.06 to 1.37
Payer									
Public	ref			ref			ref		
HMO	1.15	<0.0001	0.71 to 1.58	0.822	0.02	0.38 to 1.26	0.78	<0.0001	0.36 to 1.21
Private	0.93	<0.0001	0.59 to 1.27	1	<0.0001	0.65 to 1.35	0.88	<0.0001	0.55 to 1.22
Self pay	3.33	<0.0001	2.82 to 3.84	3.29	<0.0001	2.77 to 3.82	3.26	<0.0001	2.76 to 3.77
Other	2.27	<0.0001	1.29 to 3.24	2.14	<0.0001	1.14 to 3.27	2.16	<0.0001	1.20 to 3.12
Income									
<=2* FPL	ref			ref			ref		
2* FPL - 3* FPL	-0.35	0.03	-0.66 to -0.04	-0.25	0.12	-0.57 to 0.06	-0.30	0.05	-0.60 to 0.00
>3* FPL	-0.28	0.13	-0.64 to 0.08	-0.21	0.26	-0.58 to 0.16	-0.24	0.18	-0.59 to 0.11
Mechanism**									
Fall	ref			ref			ref		
Firearm	8.66	<0.0001	7.92 to 9.40	8.29	<0.0001	7.55 to 9.03	8.39	<0.0001	7.67 to 9.10
MVA Intent	1.51	<0.0001	1.09 to 1.94	1.48	<0.0001	1.05 to 1.90	1.51	<0.0001	1.10 to 1.92

	Population of seriously injured children including rural population (n=80,795)			Population of seriously injured children including transfer population (n=80,219)			Population of seriously injured children including rural and transfer population (n=86,934)		
	Est. *	(p)	CI	Est.	(p)	CI	Est.	(p)	CI
Unintentional	ref			ref			ref		
Intentional (suicide)	13.06	<0.0001	11.54 to 14.57	13.20	<0.0001	11.67 to 14.73	13.47	<0.0001	12.00 to 14.94
Assault	-1.49	<0.0001	-2.08 to -0.89	-1.17	<0.0001	-1.76 to -0.57	1.22	<0.0001	-1.79 to -0.64

* estimates are in percentage points

** bold indicates significance

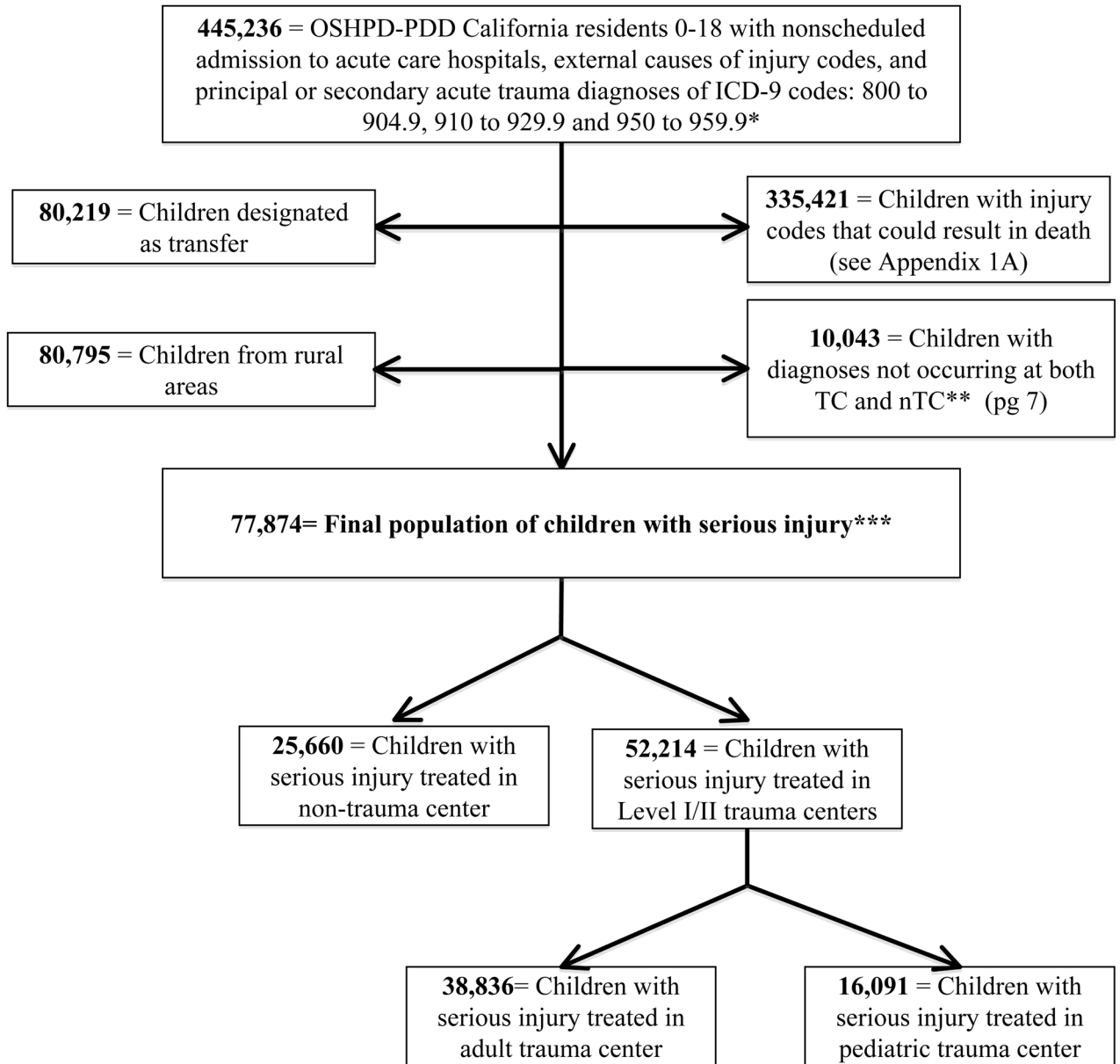


Figure 1. Derivation of patient study sample from the California Office of Statewide Health Planning and Development Patient Discharge Database (1999–2011)

*=Excludes children with sole codes indicating minor injuries, perinatal or pregnancy associated conditions, burn injuries.

**=Children cared for in level III and IV TCs were eliminated when matching TC and nTC diagnoses

***=Categories are not mutually exclusive

Table 1

Demographics of population of seriously injured pediatric trauma patients after exclusions and adjustment for difference in TC and nTC hospital case mix.

	Total	Non-Trauma Center	%	Trauma Center (TC)	%	Adult TC	%	Pediatric TC	%
Total	77,874	25,660	32.95%	52,214	67.05%	38,836	49.87%	16,091	20.66%
Total TC									
Age (yr)									
0–364 days	3,877	1,455	5.67%	2,422	4.64%	1,162	2.99%	1,246	7.74%
1–4	9,410	2,765	10.78%	6,645	12.73%	3,792	9.76%	3,050	18.95%
5–9	10,373	3,492	13.61%	6,881	13.18%	3,933	10.13%	3,266	20.30%
10–14	14,951	5,521	21.52%	9,430	18.06%	5,911	15.22%	4,155	25.82%
15–19	39,263	12,427	48.43%	26,836	51.40%	24,038	61.90%	4,374	27.18%
Gender									
Male	56,664	18,898	73.65%	37,766	72.33%	28,716	73.94%	10,870	67.55%
Female	21,203	6,760	26.34%	14,443	27.66%	10,117	26.05%	5,219	32.43%
Unknown	7	2	0.01%	5	0.01%	3	0.01%	2	0.01%
Race/Ethnicity									
White-non Hispanic	28,765	12,047	46.95%	16,718	32.02%	13,551	34.89%	5,131	31.89%
Black-non Hispanic	8,936	1,906	7.43%	7,030	13.46%	4,947	12.74%	2,053	12.76%
Hispanic	32,125	9,429	36.75%	22,696	43.47%	16,811	43.29%	6,330	39.34%
Asian	4,474	1,372	5.35%	3,102	5.94%	2,269	5.84%	878	5.46%
Native American	184	69	0.27%	115	0.22%	95	0.24%	40	0.25%
Other/unknown	3,390	837	3.26%	2,553	4.89%	1,163	2.99%	1,659	10.31%
Payer									
Public	36,441	8,736	34.05%	27,705	53.06%	19,283	49.65%	9,476	58.89%
HMO	11,738	6,179	24.08%	5,559	10.65%	3,939	10.14%	1,778	11.05%
Private	22,207	8,233	32.08%	13,974	26.76%	11,127	28.65%	4,117	25.59%
Self pay	6,053	2,227	8.68%	3,826	7.33%	3,408	8.78%	608	3.78%
Other/unknown	1,435	285	1.11%	1,150	2.20%	1,079	2.78%	112	0.70%
Income*									

	Total	Non-Trauma Center	%	Trauma Center (TC)	%	Adult TC	%	Pediatric TC	%
Total	77,874	25,660	32.95%	52,214	67.05%	38,836	49.87%	16,091	20.66%
<=2* FPL	24,060	6,538	25.48%	17,522	33.56%	13,405	34.52%	5,192	32.27%
2* FPL - 3* FPL	29,567	10,069	39.24%	19,498	37.34%	14,203	36.57%	6,411	39.84%
>3* FPL	22,153	8,289	32.30%	13,864	26.55%	10,095	25.99%	4,183	26.00%
Unknown	2,094	764	2.98%	1,330	2.55%	1,133	2.92%	305	1.90%
Disposition									
Died	4,146	972	3.79%	3,174	6.08%	2,431	6.26%	939	5.84%
Discharge	73,726	24,687	96.21%	49,039	93.92%	36,405	93.74%	15,151	94.16%
Unknown	2	1	0.00%	1	0.00%	0	0.00%	1	0.01%
Injury Mechanism**									
Fail	12,999	5,601	21.83%	7,398	14.17%	4,777	12.30%	2,816	17.50%
Firearm	9,543	2,077	8.09%	7,466	14.30%	6,285	16.18%	1,254	7.79%
MVA	29,986	7,344	28.62%	22,642	43.36%	17,138	44.13%	7,124	44.27%
Injury Type***									
Central nervous system	30,387	8,591	33.48%	21,796	41.74%	15,175	39.07%	6,775	42.10%
Abd thorax	39,419	13,449	52.41%	25,970	49.74%	19,553	50.35%	8,012	49.79%
Blood vessels	2,410	470	1.83%	1,940	3.72%	1,600	4.12%	426	2.65%
Other	18,005	5,144	20.05%	12,861	24.63%	8,978	23.12%	4,717	29.31%
Injury Severity									
Mild (iss<9)****	26,765	10,601	41.31%	16,164	30.96%	12,227	31.48%	4,665	28.99%
Moderate(9<=iss<=15)	28,623	8,905	34.70%	19,718	37.76%	14,981	38.58%	5,775	35.89%
Severe (iss>15)	22,373	6,099	23.77%	16,274	31.17%	11,608	29.89%	5,613	34.88%
ISS not listed	113	55	0.21%	58	0.11%	20	0.05%	38	0.24%

Missing data was minimal. There was no differential missing data rate by outcomes.

* Income is median household income per zipcode and is based on federal poverty level (FPL) from 2004 (\$18,850 household income)

** Injury Mechanism is based on E-code; Patients can have 0 to 5 E-codes thus the column sum can be greater than 100%. We list only the top three mechanisms of injury.

*** Injury type: Injury type is categorized according to ICD-9 groupings. We list only the most serious categories. These are not mutually exclusive.

**** ISS=Injury Severity Score

Table 2

IV regression model demonstrating estimates of treatment effect (decreased mortality) of trauma center care vs. non-trauma center care. All models have been adjusted for demographic and clinical variables as delineated in the text including: age, sex, race/ethnicity, median household income, payer status, injury severity (TSPM) and mechanism, and year.

Variable	Estimate*	(p)	CI
TC mortality affect	-0.79	0.044	-0.80 to -0.30
0-1	ref		
1-4	1.26	0.001	0.50 to 2.02
5-9	0.84	0.03	0.07 to 1.62
10-14	0.29	0.46	-0.47 to 1.04
15-19	0.37	0.32	-3.59 to 1.10
Gender			
Male	ref		
Female	-0.11	0.49	-0.42 to 0.20
Race/Ethnicity			
White non hispanic	ref		
Black non hispanic	0.36	0.15	-0.13 to 0.85
Hispanic	0.06	0.72	-0.28 to 0.40
Asian	0.87	0.01	0.27 to 1.47
Native	0.08	0.95	-2.67 to 2.83
Other	0.85	0.03	0.07 to 1.63
Payer			
Public	ref		
HMO	1.17	<0.0001	0.72 to 1.62
Private	1.03	<0.0001	0.67 to 1.39
Self pay	3.35	<0.0001	2.82 to 3.88
Other	2.18	<0.0001	1.18 to 3.19
Income			
<=2* FPL	ref		
2* FPL - 3* FPL	-0.35	0.03	-0.68 to -0.03
>3* FPL	-0.29	0.13	-0.67 to 0.09
Mechanism			
Fall	ref		
Firearm	8.62	<0.0001	7.85 to 9.39
MVA	1.51	<0.0001	1.07 to 1.95
Intent			
Unintentional	ref		
Intentional (suicide)	13.15	<0.0001	11.57 to 14.73
Assault	-1.47	<0.0001	-2.08 to -0.85

Regression diagnostics: The partial F of 210.52 falls well above the recommended value of 30 for a superior instrument.⁴⁰

* Estimates are in percentage points

** bold indicates significance

Table 3

Regression models demonstrating treatment estimates of effect (decreased mortality) of pediatric trauma center care vs. adult trauma center care.

All models have been adjusted for demographic and clinical variables as delineated in the text including: age, sex, race/ethnicity, median household income, payer status, injury severity (TMPM) and mechanism, and year.

Population (n=52,214; unadjusted mortality: 6.5%)	Estimate*	(p)	CI
Pediatric Trauma Center vs. Adult Trauma Center Care			
Trauma center mortality effect	0.64	0.16	-0.26 to 1.54

Regression diagnostics: The partial F of 219.7 is well above the recommended value of 30 for a superior instrument.⁴⁰

* Estimates are in percentage points