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Thomas J. Flottemesch
Truven Health Analytics, thomas.flottemesch@truvenhealth.com

Susan Raetzman
Truven Health Analytics

Kevin C. Heslin
Agency for Healthcare Research and Quality

Katie Fingar
Truven Health Analytics

Rosanna Coffey
Truven Health Analytics

See next page for additional authors

Authors
Thomas J. Flottemesch; Susan Raetzman; Kevin C. Heslin; Katie Fingar; Rosanna Coffey; M.L. Barrett, Inc.; and Ernest Moy

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Author List:

Thomas J. Flottemesch, PhD[1]
Susan Raetzman, MSPH[1]
Kevin C. Heslin, PhD[3]
Katie Fingar, PhD[1]
Rosanna Coffey, PhD[1]
Marguerite Barrett, MS[2]
Ernest Moy, MD, MPH[4]

1. Truven Health Analytics
2. M.L. Barrett, Inc.
3. Agency for Healthcare Research and Quality
4. Affiliation during this investigation: Agency for Healthcare Research and Quality
   Current affiliation: Centers for Disease Control and Prevention

Corresponding Author:
Thomas J. Flottemesch
100 Phoenix Drive
Ann Arbor, MI 48108
e-mail: Thomas.Flottemesch@TruvenHealth.com
Phone: 612-615-4802

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Conflicts of Interest

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Abstract

Objective: In 2006, the American College of Surgeons' Committee on Trauma and the Center for Disease Control released field triage guidelines with special consideration for older adults. Additional considerations for direct transport to a Level I or II trauma center (TC) were added in 2011, reflecting perceived undertriage to TCs for older adults. We examined whether age-based disparities in TC care for severe head injury decreased following introduction of the 2011 revisions.

Methods: A pre-post design analyzing the 2009 and 2012 Healthcare Cost and Utilization Project State Emergency Department Databases (SEDD) and State Inpatient Databases (SID) with multivariable logistic regressions considered changes in (1) the trauma designation of the emergency department where treatment was initiated and (2) transfer to a TC following initial treatment at a non-TC.

Results: Compared with adults aged 18–44 years, after multivariable adjustment, in both years TC care was less likely for adults aged 45–64 years (OR: 0.76 in 2009 and 0.74 in 2012), aged 65–84 years (OR: 0.61 and 0.59), and aged 85+ years (OR: 0.53 and 0.56). Between 2009 and 2012, the likelihood of TC care increased for all age groups, with the largest increase among those aged 85+ years (OR = 1.18), which was statistically different (p = .02) from the increase among adults aged 18–44 years (OR = 1.12). The analysis of transfers yielded similar results.

Conclusions: Although patterns of increased TC treatment for all groups with severe head trauma indicate improvements, age-based disparities persisted.

Both the proportion and number of older adults in the United States are expected to grow considerably in upcoming decades. Projections by the U.S. Census Bureau[1] indicate that the population aged 85 years and older is likely to increase from an estimated 4 million in 2000 to over 19 million by 2050. This aging of the U.S. population presents unique health care challenges. Chronic conditions are more prevalent among older adults, and the need for age-appropriate changes in treatment is more acute.[2,3]

One area in which patients' needs differ considerably by age is trauma care. [4] Older patients with traumatic injuries present differently, recover more slowly, and require a different process of care.[5–8] They typically respond differently because of age-related changes that decrease physiologic reserve and ability to respond positively to aggressive resuscitation.[7] Treatment is further complicated by factors such as heart rate and blood pressure, which distinguish severe cases among other adult populations but may become unreliable indicators among older adults.[9–11]

This confluence of factors has resulted in identified patterns of undertriage associated with poorer outcomes[9,12–15] such as higher rates of trauma-related morbidity and mortality among older patients.[16–18] Possible causes for these age-related triage disparities include patient-level variables such as payer status,[19] differences in initial presentation,[2,19,20] location of injury,[21] type of injury,[22] and geographic distance from the nearest emergency department (ED).[23,24]

In 1986, the American College of Surgeons (ACS) published the first Field Decision Scheme, which was updated in 1990, 1993, and 1999. In 2006, the ACS Committee on Trauma (ACS-COT) and the Centers for Disease Control and Prevention (CDC) jointly published an updated field triage guideline that included a special consideration for adults aged 55 years and older. In 2011, as part of another update, two age-related considerations were added and the criteria for patients with anticoagulation modified.[10] The first age-based criterion was direct transport to a high-level (Levels I and II) trauma center (TC) for patients with a systolic blood pressure <110, which may be indicative of shock for patients older than 65 years of age. The second was direct transport to a TC for low-impact mechanisms that might result in severe injury for patients older than 55 years of age. Direct transport to a high-level trauma center was also recommended for anticoagulated patients.

Unfortunately, uptake of even the 2006 update appears slow and variable.[25] Studies of triage patterns during the years following that revision suggest that the age-based criterion introduced in 2006 was inadequate[12,18,25] and that additional age-based criteria would improve field triage of patients aged 70 years and older.[9]

There have been few evaluations of the 2011 revision. Most studies used data collected prior to 2010. One study sought to validate the updated guidelines for motor vehicle crashes and found that additional age-specific criteria may be needed for this mechanism of injury.[26] Another study found an inverse association between having insurance and the likelihood of transfer to a Level I or II TC.[19] A third evaluation found the current mechanism of injury guidelines to be accurate except for vehicle intrusion and motor cycle crash.[27] The one study that used data after the latest guideline change did not include a comparison to an earlier point in time.[28]

For this study, we used a retrospective pre and postguideline design to evaluate the potential impact of the 2011 revision on disparities across age groups.[29] We used hospital databases from 31 states and focused on a specific injury—severe head trauma with an Abbreviated Injury Scale (AIS) of 4 or higher. The primary outcome of the study was the trauma designation of the initial treating ED, which served as a proxy for the field triage decision. We compared observed rates of initial treatment at Level I and II (versus Levels IV or V) TCs during 2009 (preguideline) with those during 2012 (postguideline). In a secondary analysis, we compared 2009 and 2012 rates of transfer to a TC following initial treatment at a non-TC.

METHODS

We analyzed encounters (ED visits and inpatient admissions) among severe head trauma cases originating with ED treatment. We used data from the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID) for 2009 and 2012. The SEDD capture visits at hospital-owned EDs not resulting in admission. The SID capture hospitalizations including those starting in the ED. There were 31 states with SEDD and SID in both 2009 and 2012. Eleven contained patient linkage numbers allowing tracking of transfers within a state for a given year. We also extracted hospital characteristics from the American Hospital Association Annual Survey and the trauma level of the hospital from the Trauma Information Exchange Program database.[30] The HCUP databases are consistent with the definition of limited data sets under the Health Insurance Portability and Accountability Act Privacy Rule and contain no direct patient identifiers. The AHRQ institutional review board does not consider use of HCUP data human subjects research.

Identification of Study Sample

The ICD Programs for Injury Categorization (ICDPIC)[31] were used to translate ICD-9 diagnosis codes into standard injury categories and scores. Encounters for adults with severe head trauma injury were identified using the following inclusion criteria: aged 18 years and older; head injury with an AIS of 4 or higher, and treatment at an ED with a TC or non-TC designation. We excluded transfers into the ED from another acute care hospital as indicated by the point of origin. We also excluded cases that initially were treated at Level III TCs. Level III TCs need to have established transfer arrangements with a TC,[30] because at certain times of the day the Level III TC may have on-site facilities that make them similar to a TC, but during off times when these capacities are unavailable, the Level III TCs are more similar to non-TCs. Thus, although the distinction between care provided by TCs (which includes 24-hour immediate coverage and access to surgery and critical care) and non-TCs (which are not required to have surgical or critical care support) is clear-cut, the care provided by Level III TCs varies, and HCUP databases do not track which hospital facilities are available at the time of a patient encounter.

Study Variables

The primary outcome was whether initial treatment for severe head trauma was at a TC or a non-TC. A secondary outcome, available for 11 states with patient linkage numbers, was whether transfers to a TC followed initial non-TC treatment. The SEDD discharge-status variable for each state, which distinguishes cases transferred to another short-term hospital from those released from the ED, was not always available; therefore, we used an alternative definition to identify all transfers. We identified transfers as any person with a severe head trauma injury initially treated at a non-TC who was not admitted to that non-TC and had a corresponding encounter at a TC within 1 day of discharge. Our two key independent variables were patient age and year of encounter. The two field triage guideline revisions focused on slightly different age groups: one targeted patients aged 55 years or older, and the other targeted patients aged 65 years or older. Following prior studies,[18] which found the greatest disparities when using standard age groupings,[29] we grouped age as follows: 18–24 years, 25–44 years, 45–64 years, 65–84 years, and 85 years or older.

For both the primary and secondary analyses, we adjusted for several factors that could influence the ED of initial treatment. These factors fell into four categories: (1) demographics, (2) factors related to case severity, (3) factors related to patient complexity, and (4) area-level factors.

Demographic variables included sex, location of residence, and expected payer. Location was categorized as large central metropolitan, large fringe metropolitan, medium metropolitan, small metropolitan, micropolitan, and noncore. The expected payer categories were private, Medicaid, Medicare, uninsured/self-pay, other, and unknown or missing.

Factors related to injury severity were the ISS, location of injury, mechanism of injury, type of injury, and secondary diagnoses. The ISS, which is a validated, anatomical scoring system that assesses overall injury severity for patients with multiple injuries,[32] accounted for polytrauma. Location of injury was based on patient self-report, mechanism of injury was identified from principle diagnosis and E codes, and the number of secondary diagnoses was identified from diagnostic codes. We tracked four major types of injury: intracranial, spinal cord, open wound, and fracture. The number of secondary diagnoses were categorized as zero, one, two, and three or more.

We used the Agency for Healthcare Research and Quality (AHRQ) Comorbidity Measures algorithm[33] to identify comorbidities and classified patients as having zero, one, two, or three or more. Thirteen comorbidities had a prevalence of 5% or greater, and we used indicator variables to make further adjustment for these specific comorbidities.

Area-level factors included hospital-level characteristics and other environmental factors that could influence where patients were initially treated.[34–36] The hospital-level characteristics were region (Northeast, Midwest, South, and West), hospital location (large central metropolitan, large fringe metropolitan, medium metropolitan, small metropolitan, micropolitan, and noncore), payer mix (private, Medicaid, Medicare, uninsured/self-pay, and other), bed size, teaching status, and ownership (public, private nonprofit, and investor-owned). The environmental factors included the number of TCs located within 5, 15, and 30 miles of the initial treating ED, measured using the geocoded location of the initial treating ED and alternative TCs. Because we measured distance in terms of direct line of sight, distance for rural hospitals likely understates actual transportation time.

Analytic Approach

All analyses was performed in SAS 9.4. First we determined the descriptive statistics of each demographic, case severity, patient complexity, and area-level factor by the primary outcome. To ensure more precise estimates of our effects of interest, we excluded from multivariable analysis factors that had a prevalence of less than 5% or greater than 95% within one or more categories.

Once tabulated, we used bivariate methods to test associations between each demographic, case severity, patient complexity, hospital, and area-level factor for the outcomes. All factors found significant in the bivariate analysis were included in multivariable models regardless of their significance after multivariable adjustment. Other factors, such as hypertension and paralysis, not found significant in bivariate analysis were considered and retained in the final multivariable models if the model's likelihood ratio test was significant at the 5% level. Alternative specifications, transformations, and interactions were considered in the final specification when appropriate.

Two multivariable logistic regressions analyzed the primary and secondary outcomes. We constructed all multivariable models in a bottom-up, iterative manner. Demographic variables were considered first, followed by injury complexity, patient complexity, and hospital- and area-level factors. Generalized R-squared assessed the final model's overall goodness of fit.

To assess whether change in the use of TCs differed by age group, we added an interaction term multiplying age category by a year indicator. The four resulting estimates captured the change from 2009 to 2012, and post estimation Wald tests identified significant differences between age groups. To highlight initial treatment at TC versus non-TC EDs, we estimated marginal differences at the sample mean of all included covariates.

RESULTS

The final sample of 140,766 cases included 74,632 initially treated at TCs and 66,134 initially treated at non-TCs. Further detail on study inclusion and exclusion criteria is available in the Appendix (Figure A1). The secondary analysis, examining transfers to TCs from non-TCs, included only cases with available information about such transfers (n=30,510). Because initial comparisons showed no differences between the 18–24 and 25–44 year groups, they were combined.

Table 1 provides descriptive statistics of characteristics based on the combined 2009 and 2012 data.

Compared with patients treated at TCs, those treated at non-TCs were more likely to be younger (24.5% vs. 12.7% aged 18–44 years), to be male (63.4% vs. 54.5%), and to live in large central metropolitan areas (31.6% vs. 28.9%), whereas they were less likely to have Medicare (47.0% vs. 64.7%) and to have been injured at home (20.4% vs. 26.3%) or in a fall (52.5% vs. 68.7%). Patients treated at TCs also had fewer secondary diagnoses (74.4% vs. 77.8% with 3+ diagnoses) and comorbidities (31.1% vs. 34.5% with 3+ comorbidities) and were less likely to have intracranial injuries (71.1% vs. 87.7%).

Table 2 summarizes the number and average distance from the initial treating ED to alternative TCs. Relative to those treated at non-TCs, patients treated at TCs had a greater number of alternative TCs within 5 (.85 vs. .46), 15 (3.18 vs. 2.26), and 30 (6.39 vs. 4.99) miles; however, the distance to the nearest alternative TC was actually shorter for those initially treated at a non-TC (38.87 vs. 21.24).

Likelihood of Initial Treatment at a TC

Descriptive Comparisons. We found substantial age-based differences in treatment at TCs (Figure 1). The percentage of patients initially treated at a TC decreased with age, such that adults aged 85 years and older had the lowest prevalence of initial treatment at a TC both in 2009 (40.3%) and in 2012 (43.5%). By comparison, the percentage of adults aged 18–44 years treated at a TC was 67.5% in 2009 and 69.7% in 2012.

Multivariable Analysis. Results from the multivariable analyses for our effects of interest (age and year) are shown in Table 3. We found those aged 65–84 years as well as those 85 years and older significantly less likely than 18–44 year olds to be initially treated at a TC in 2009 ($OR_{65–84}$=.61; OR_{85+}=.53) and 2012 ($OR_{65–84}$=.59; OR_{85+}=.56). Comparing 2012 with 2009, the largest increase in the likelihood of initial treatment at a TC was again among those 85 years and older (OR = 1.18) followed by those aged 18–44 years (OR = 1.12), with the older group having a significantly larger increase (p = .02).

The results from the full multivariable model are illustrated in Figure 1. After adjustment, age-based disparities in the likelihood of initial treatment at a TC were attenuated but persisted.

Likelihood of Transfer from Non-TCs to TCs

Subsample Comparison. Transfer to a trauma center following stabilization is a potential sign of proper, effective. In secondary analysis, we examined this possibility among a subset of the sample (n=52,757) from the eleven states with patient-level identifiers that allowed tracking across hospitals. Relative to the 88,009 excluded cases from states that did not have some patient-level identifiers, this subset tended to be older (60.5% versus 57%; p<001), live in metro areas (80.4% versus 72.9%; p<.001), and insured by Medicare or Medicaid (67% versus 61%). However, case severity and patient complexity were similar. 61% (versus 64%) had three or more secondary diagnoses, 54% (versus 55%) had at least one comorbidity, and 72% (versus 71%) suffered an intracranial injury.

Descriptive Comparisons. Figure 2 illustrates how the percentage of all patients with severe head trauma who ultimately were transferred to a TC from a nonTC (the "NT to TC" category) was similar across age groups. However, a considerable age disparity appears when these percentages are expressed as proportions of those initially treated at a non-TC. In 2012, out of all patients initially treated at a non-TC, the percentage of patients transferred to a TC was 19.3% for adults aged 85 years and older compared with 34.6% for adults aged 18–44 years.

Multivariable Analysis. Table 4 shows the results of a multivariable logistic regressions considering the likelihood of transfer to a TC among cases initially treated at a non-TC. Transfer to a TC from a non-TC was most likely among those in the 45–64-year age group in 2009 (OR_{2009}=1.50; OR_{2012}=1.28) as well as the 65–84-year age group in 2009 (OR_{2009}=1.28; OR_{2012}=1.30). The difference in adjusted and unadjusted estimates appears to stem from the different prevalence of comorbidities across age groups and how those comorbidities affect both the likelihood of admission as well as the likelihood of transfer (Appendix Table A1).

DISCUSSION

Our goal was to determine whether age-based disparities in undertriage after the 2011 update persisted. We designed this study to permit an assessment of the impact that the updated guidelines had on treating trauma in older patients. Our focus on severe trauma cases (AIS≥4), which has been used elsewhere to indicate undertriage,[14] provided reasonable confidence that initial triage to a TC was the best outcome for this population. Also, we used large datasets from multiple states with a variety of variables to provide one of the largest and most comprehensive evaluations of the 2011 revision.

This evaluation of the status of age-based disparities in undertriage after the 2011 update indicated that patterns of initial TC treatment and TC transfer for severe head trauma increased for all groups, particularly among adults aged 85 years or older. However, age-based disparities were still apparent in 2012. The results of this study build on prior work in several important ways. First, several previous studies that identified age-based disparities in trauma care used databases that were limited to individual states[15,18,19,34,37] or hospital types.[38] This study is one of the first[22,25,38] to use a pooled sample of hospitals from 31 states, which provides insight into larger trends. Second, because the combined HCUP databases include data from hospital admissions as well as ED discharges, we were able to account for a larger number of factors concerning injury severity, patient complexity, and area-level factors. Although the study was restricted to a subset of states, we also were able to verify transfers following initial treatment. This study also makes a unique contribution in that it examined a specific type of injury, severe head trauma, at two points in time—before and after the field triage guideline revisions. Finally, the focus on a severe head trauma injury for which triage to a TC is highly desirable allowed us to draw clear contrasts regarding patterns of care across age groups and time, with any observed differences by age group and across time most likely attributable to differences in age or the impact of revised guidelines.

In this study we assessed the impact of recent changes to the field triage guidelines.[39] Other investigations have discussed the value of mechanism-specific as well as age-specific guidelines[26,40] in reducing overtriage and undertriage[41] as a means of improving care and reducing cost.[42] In this study we focused on a specific injury and previously identified disparities across age groups.[14,43,44] We found that the likelihood of initial treatment for severe head trauma at a TC increased from 2009 to 2012 among all patients. At the same time, results across our estimated models (Table 2) suggest that injury severity and clinical complexity are influential factors. Adjustment for injury severity, such as ISS and number of secondary diagnoses, decreased estimated disparities across the four age groups, whereas further adjustment for clinical complexity increased disparities.

Our key result is that, although rates of initial treatment at a TC increased slightly more among those aged 85 and older relative to younger adults, age-based disparities in the initial treatment of severe head injury persisted. This finding suggests that the revised guidelines may be having a positive, if modest, impact that is likely to increase as their use increases.[25] There were three relevant guideline changes that need to be considered: two age-based criteria and a modification for anticoagulated patients who tend to also be older. Given these simultaneous modifications, we cannot determine if, or which, or the purely age-related revisions are driving the observed change, because our data do not provide information regarding pharmacotherapy prior to hospital presentation. Future studies that consider a longer adoption period with refined patient-level data will be important for determining whether the trend continues.

We also examined patterns of transfer to a TC following initial treatment at a non-TC, an important aspect of adequate and safe trauma care access.[16,34,37,44] Most non-TCs have transfer agreements for severe injuries,[30] and a transfer from a non-TC to a TC is a potential sign of proper, effective care.[19,35] Similar to our findings on initial treatment at a TC, we found that all age groups experienced higher rates of transfer in 2012 compared with 2009. Interestingly, the largest increases occurred among the oldest (85 years and older) age group. Unfortunately, this secondary analysis was limited to 11 states that tended to be located in the Northeast and the South. Consequently, the change in transfer rates identified in our secondary analysis may reflect regional differences in the rate of adoption of the new guidelines[25] and not nationwide patterns of care. The subset of cases used in the secondary analysis also differed from the full sample in that patients tended to be older, to live in metro areas, and to have Medicare or Medicaid. However, injury severity and patient complexity was similar. Consistent with other studies,[18,38,43,45] we found that these additional factors were indicative of the location of initial treatment as well as the likelihood of subsequent transfer.

Finally, the higher percentage of transfers among adults aged 65–84 years shown in Figure 2 both complement and partially contradict other studies. On the one hand, a population-based examination of traumatic brain injury hospitalizations and transfers in the Trauma Data Bank National Sample Population found higher transfer rates for adults aged 55 years and older in 2012 compared with children and adults younger than 55 years.[28] On the other hand, a 2014 study that used the HCUP National Emergency Department Sample (NEDS) found significant differences by primary payer in 2009 patterns of transfer.[19] Specifically, that study found that Medicare patients, most of whom are aged 65 years or older, were significantly less likely to be transferred. Although insurance coverage was not the focus of our inquiry, we did adjust for expected payer in our multivariable models with similar results; as Figure 2 indicates, we also found that older patients were less likely to be transferred. However, we attribute any other differences to outcome definition. The authors of the 2014 study leveraged the requirements of the Emergency Medical Treatment and Labor Act, defining a transfer as any transfer from a non-TC. In contrast, the current study defined a transfer in terms of corresponding hospital records within a state. In addition, the

NEDS, which was used in the 2014 study, is intended to be a nationally representative sample, whereas, as noted, the states in the SID and SEDD that we were able to include in our transfer analysis are not.

LIMITATIONS

This study used a large, nationwide, observational dataset to examine patterns of initial triage and subsequent transfer to a TC. As with any study using administrative data, we encountered difficulties regarding the completeness, consistency, and comparability of available observations. Our findings cannot be viewed as nationally representative because we were able to include data from only 31 states (those that provided 2009 and 2012 ED and inpatient data) in the primary analysis and data from a subset of 11 states (those with patient linkage numbers) in the secondary analysis. We were able to adjust for the availability of alternative treatment locations (TCs within three specified distances) at the hospital level but not on an injury-by-injury basis, because the exact location of each injury was not known. This is notable, because adjustment for area-level factors made a significant difference in model goodness of fit (Appendix).

Our use of the same data to identify comorbidities as well as key outcomes introduced the risk of coupling injury severity and case complexity in unintended ways. The accuracy of the AHRQ Comorbidity Measures algorithms increases as the amount of available data increases. Thus, comorbidities are more likely to be identified in patients who have more severe injuries that result in greater amounts of clinical data during longer hospital encounters that incorporate more procedures. For instance, the average number of comorbidities among cases discharged from the ED was 0.95, whereas the average number of comorbidities among those admitted was 2.4 (Appendix Table A2). However, the correlation between length of stay and the number of comorbidities was moderate ($r = .22$); this potential risk did not appear to be a significant issue, because area-level factors had the largest impact on overall model fit (as evidenced by the generalized R^2 for the models presented in Tables 2 and 3).

In addition, our time frame may not have been long enough to provide a full determination of the impact of the revised field triage guidelines. Others have found significant differences in the use of field triage guidelines,[25] and a longer time period may be needed to provide a full assessment of the impact of this policy.

Finally, similar to related studies that employed administrative data[18,19,28,43], we were neither able to observe initial patient presentation, subsequent field triage decision, nor the exact mode of transport to the initial treating emergency department. Thus, any conclusions drawn from our analysis must be placed in the context of this limitation and should not be interpreted as a definitive. Instead, they are supportive of greater investigation of field decision by emergency medical service providers.

CONCLUSIONS

We found that patterns of TC treatment increased for all groups, particularly for adults aged 85 years or older, but that age-based disparities in the treatment of severe head trauma persisted even after introduction of new field triage guidelines. It appears that there has been improved triage to TCs for patients of all ages who experience severe head injury. This may be due in part to increased awareness associated with the field guidelines. However, given that a portion of the updated field guidelines focused specifically on care for older adults, it is concerning that we did not see a more pronounced improvement in the disparity in undertriage between older and younger adults. This result indicates that continued monitoring of triage and referral patterns for older patients experiencing severe trauma is needed as the guidelines continue to be adopted and refined.

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Table 1: Characteristics of adults with severe head trauma initially treated at trauma and nontrauma center hospitals (N=140,766)[1]

	Trauma Center[2]		Nontrauma Center[2]		
Characteristic	N	%	N	%	p-value
All patients	74,632	100	66,134	100	
Year					
2009	35,162	47.1	32,209	48.7	<.001
2012	39,470	52.9	33,925	51.3	
Age, y					
18–44	18,321	24.5	8,390	12.7	<.001
45–64	19,152	25.7	12,745	19.3	
65–84	24,913	33.4	28,116	42.5	
85+	12,246	16.4	16,883	25.5	
Sex					
Male	47,334	63.4	36,036	54.5	<.001
Female	27,279	36.6	30,086	45.5	
Expected payer					
Medicare	35,067	47.0	42,782	64.7	<.001
Medicaid	7,732	10.4	3,810	5.8	
Private	18,670	25.0	11,829	17.9	

Uninsured	8,357	11.2	5,292	8.0	
Other	4,561	6.1	2,238	3.4	
Unknown or missing	245	0.3	183	0.3	
Location of residence[10]					
Large central metropolitan	23,613	31.6	19,095	28.9	<.001
Large fringe metropolitan	17,493	23.4	16,877	25.5	
Medium metropolitan	17,677	23.7	11,817	17.9	
Small metropolitan	5,479	7.3	4,877	7.4	
Micropolitan	5,790	7.8	8,166	12.3	
Noncore	3,783	5.1	4,815	7.3	
Unknown or missing[9]	797	1.1	487	0.7	
Location of accident[3]					
Home	15,224	20.4	17,375	26.3	<.001
Institution	3,817	5.1	4,595	6.9	
Other location	10,558	14.1	10,272	15.5	
Street	7,780	10.4	2,697	4.1	
Unknown or missing[9]	37,253	49.9	31,195	47.2	
Type of accident[4]					
Falls	39,168	52.5	45,416	68.7	<.001
Transport	16,947	22.7	5,746	8.7	
Adverse effects	3,722	5.0	2,632	4.0	
Self-inflicted	1,602	2.1	445	0.7	
Other specific	7,036	9.4	4,337	6.6	
Nonspecific	3,553	4.8	4,715	7.1	
Unknown or missing[9]	2,604	3.5	2,843	4.3	
Secondary diagnoses					
0	9,964	13.4	4,294	6.5	<.001
1	4,330	5.8	4,911	7.4	
2	4,828	6.5	5,471	8.3	
3+	55,510	74.4	51,458	77.8	
Injury type[5,6]					
Intracranial	53,065	71.1	57,979	87.7	0.290
Spinal cord	2,592	3.5	2,632	4.0	
Fracture	2,020	2.7	2,257	3.4	
Open wound	722	1.0	1,081	1.6	
Comorbidity distribution					
0	23,227	31.1	17,159	25.9	<.001
1	15,006	20.1	14,018	21.2	
2	13,168	17.6	12,166	18.4	
3+	23,231	31.1	22,791	34.5	
Specific comorbidities[7,8]					
Hypertension	34,546	46.3	32,956	49.8	<.001
Fluid and electrolyte disorders	14,316	19.2	14,118	21.3	<.001
Other neurological disorders	13,584	18.2	12,665	19.2	<.001
Diabetes without chronic complications	11,072	14.8	10,747	16.3	<.001

Alcohol abuse	8,993	12.0	8,516	12.9	<.001
Deficiency anemias	8,266	11.1	7,837	11.8	<.001
Chronic pulmonary disease	6,825	9.1	6,796	10.3	<.001
Hypothyroidism	6,228	8.3	6,373	9.6	<.001
Congestive heart failure	5,656	7.6	5,181	7.8	0.07
Depression	5,321	7.1	5,287	8.0	<.001
Renal failure	5,255	7.0	5,291	8.0	<.001
Coagulopthy	4,167	5.6	4,222	6.4	<.001
Paralysis	4,197	5.6	3,736	5.6	0.84

1. Cases are from states in both the 2009 and 2012 State Inpatient Databases and State Emergency Department Databases. A case is defined as an identified head trauma injury initially treated at either a trauma center or nontrauma center that encompasses subsequent hospital admissions or transfers within 1 day of discharge. An individual may contribute more than one case, but this is identifiable for only a subset of states.
2. Descriptive statistics across all included cases that were limited to an injury severity score of 16 or greater.
3. Location of accident was identified using E codes. To identify a single location for the 597 cases with multiple places, the following hierarchy was used (in ascending order of importance): street (highest), institution, home, other, and unknown or missing (lowest).
4. Type of accident was identified using E codes. To identify a single type for the 6,179 cases with multiple injuries, the following hierarchy (in ascending order of importance) was used: transport injury (highest), self-inflicted, fall, adverse effect, other specific injury, other nonspecific injury, and unknown or missing (lowest).
5. The listed injury types are not exhaustive and are only the four highest frequency injury types included in the final multivariable models. Thus, percentages do not sum to 100%.
6. A Chi-Square test of association was used to compare distribution of cases across the highest-frequency injury types. The occurrence of specific injury types was not compared. Thus, while intracranial injuries were more common among those initially treated at non-trauma centers, the mix across the four categories was not.
7. Comorbidities were identified using the Agency for Healthcare Research and Quality Comorbidity Measures algorithm.
8. Percentages sum to more than 100 as a result of numerous patients' having more than one comorbidity.
9. An indicator variable for Unknown or Missing was used to account for this category in the final multivariable model.
10. Based upon county and urban-rural classification scheme for U.S. counties developed by the National Center for Health Statistics (NCHS)

Table 2: Average number and distance from initial treating emergency department to nearest alternative trauma center(TC)[1]

Trauma Designation of initial treating emergency department:	Trauma Center[2] Mean	SD	Nontrauma Center Mean	SD	p-value[3]
Number of Alternative TCs					
Within 5 miles[4]	.85	.03	.46	.03	<.001
Level I	.62	.05	.35	.04	<.001
Level II	.23	.01	.11	.02	<.001
Within 15 miles[4]	3.18	.12	2.26	.84	<.001
Level I	1.97	.1	1.51	.15	<.001
Level II	1.19	.15	.75	.02	<.001
Within 30 miles[4]	6.39	.22	4.99	.18	<.001
Level I	3.45	.25	2.94	.2	<.001
Level II	2.94	.2	2.05	.16	<.001
Distance to Nearest Trauma Center[5]	38.87	.78	21.24	.1	<.001

1. Cases are from the 31 states in both the 2009 and 2012 State Inpatient Databases and State Emergency Department Databases. A case is defined as an identified head trauma injury initially treated at either a trauma center or nontrauma center that encompasses subsequent hospital admissions or transfers within 1 day of

discharge. An individual may contribute more than one case, but this is identifiable for only a subset of states (11).

2. Calculated counts and distances are exclusive of the initial treating emergency department
3. Results from bi-variate t-test comparing cases initially treated at a trauma center with those treated at a nontrauma center.
4. Included as covariate in multivariable model (Tables 3 and 4)
5. Due to their high collinearity, only the set of count variations (Alternative TC within 5, 15, or 30 miles) or the Distance to Nearest TC were considered for inclusion into final multivariable models. Generalized likelihood ratio tests indicated the model including the count variables provided better fit, and this variable was excluded.

Table 3. Age Disparities in the Odds of Initial Treatment at a Trauma Center for Adults With Severe Head Trauma (N = 140,766)*

Year/Age Group	OR	Lower	Upper
2009 (Ref=18–44)			
45–64	0.76	0.71	0.81
65–84	0.61	0.56	0.65
85+	0.53	0.49	0.57
2012 (Ref=18–44)			
45–64	0.74	0.69	0.80
65–84	0.59	0.54	0.63
85+	0.56	0.51	0.60
2012 vs. 2009**			
18–44	1.12	1.04	1.20
45–64	1.10	1.03	1.16
65–84	1.08	1.03	1.13
85+	1.18	1.11	1.25
Gen. R^2	*0.56*		

Gen. R^2 = generalized R squared; lower = lower limit of 95% confidence interval, OR = odds ratio, Ref = reference, Upper = upper limit of 95% confidence interval.

* All estimates are from a single logistic regression examining the likelihood of initial treatment at a Trauma Center that included the following covariates: Demographic (sex (p<.001), location of residence (p<.001), and expected payer (p<.004)); Injury (location of accident (p<.001), type of accident, injury severity score, number of secondary diagnoses, and indicators for intracranial, spinal, and fracture-related injury); Clinical Complexity (number of comorbidities, indicators for hypertension, electrolyte disorders, neurologic disorders, diabetes, alcohol abuse, deficiency anemias, pulmonary disease, hypothyroidism, chronic lung disease, congestive heart failure, depression, paralysis, renal failure, and coagulopathy); Geography (hospital region, ownership, and number of level 1 and level 2 trauma centers within 5, 15, and 30 miles of initial treating emergency department);

**For each age group, the change in odds of initial treatment at a Trauma Center in 2012 compared to 2009 were computed using and age group*year interaction terms at that sample wide average value of all other covariates (Table 1).

Table 4. Age Disparities in Odds of Transfer to a Trauma Center After Initial Treatment at a Nontrauma Center for Adults With Severe Head Trauma, 2009 and 2012 (N = 30,510)*

Year/Age Group	**OR**	**Lower**	**Upper**
2009 (Ref=18–44)			
45–64	1.50	1.29	1.75
65–84	1.28	1.10	1.50
85+	0.97	0.82	1.16
2012 (Ref=18–44)			
45–64	1.28	1.10	1.49
65–84	1.30	1.12	1.52
85+	1.03	0.86	1.22
2012 vs 2009**			
18–44	1.30	1.11	1.53
45–64	1.11	1.00	1.27
65–84	1.32	1.17	1.46
85+	1.37	1.21	1.56
Gen. R^2	*0.36*		

OR = odds ratio; lower = lower limit of 95% confidence interval; upper = upper limit of 95% confidence interval; Ref = reference.

* All estimates are from a single logistic regression examining the likelihood of transfer to a Trauma Center following initial treatment at a non-trauma center that included the following covariates: Demographic (sex (p<.001), location of residence (p<.001), and expected payer (p<.004)); Injury (location of accident (p<.001), type of accident, injury severity score, number of secondary diagnoses, and indicators for intracranial, spinal, and fracture-related injury); Clinical Complexity (number of comorbidities, indicators for hypertension, electrolyte disorders, neurologic disorders, diabetes, alcohol abuse, deficiency anemias, pulmonary disease, hypothyroidism, chronic lung disease, congestive heart failure, depression, paralysis, renal failure, and coagulopathy); Geography (hospital region, ownership, and number of level 1 and level 2 trauma centers within 5, 15, and 30 miles of initial treating emergency department);

**For each age group, the change in odds of initial treatment at a Trauma Center in 2012 compared to 2009 were computed using and age group*year interaction terms at that sample wide average value of all other covariates (Table 1).

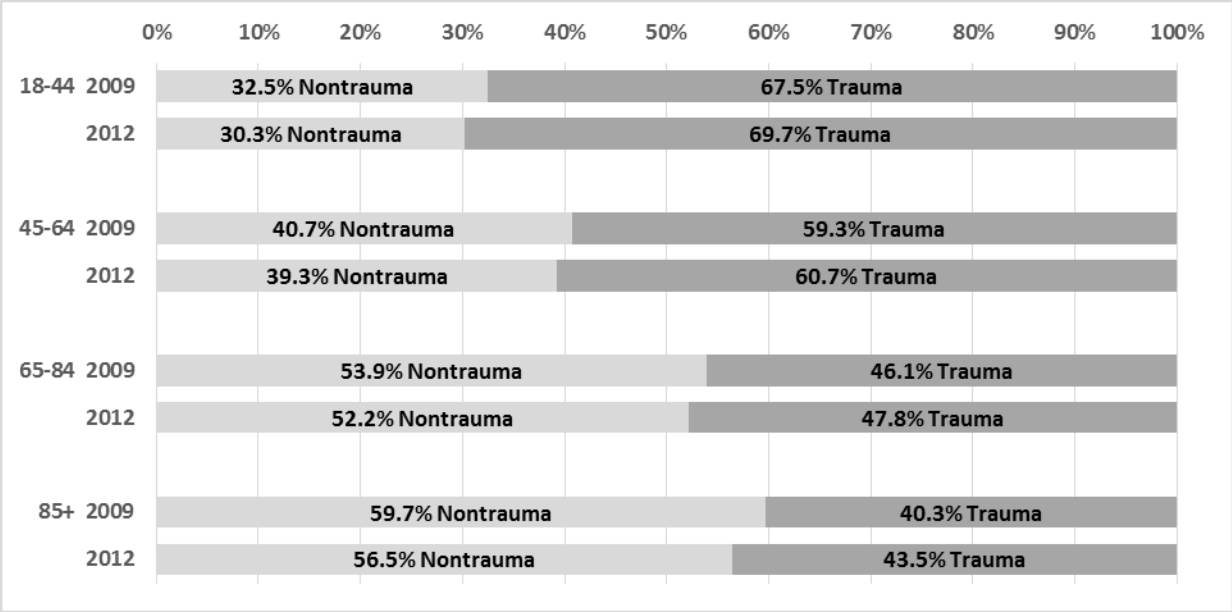

Figure 1. Observed rates of initial treatment at trauma and nontrauma center hospitals by age and study year among adults with severe head trauma (N = 140,766).

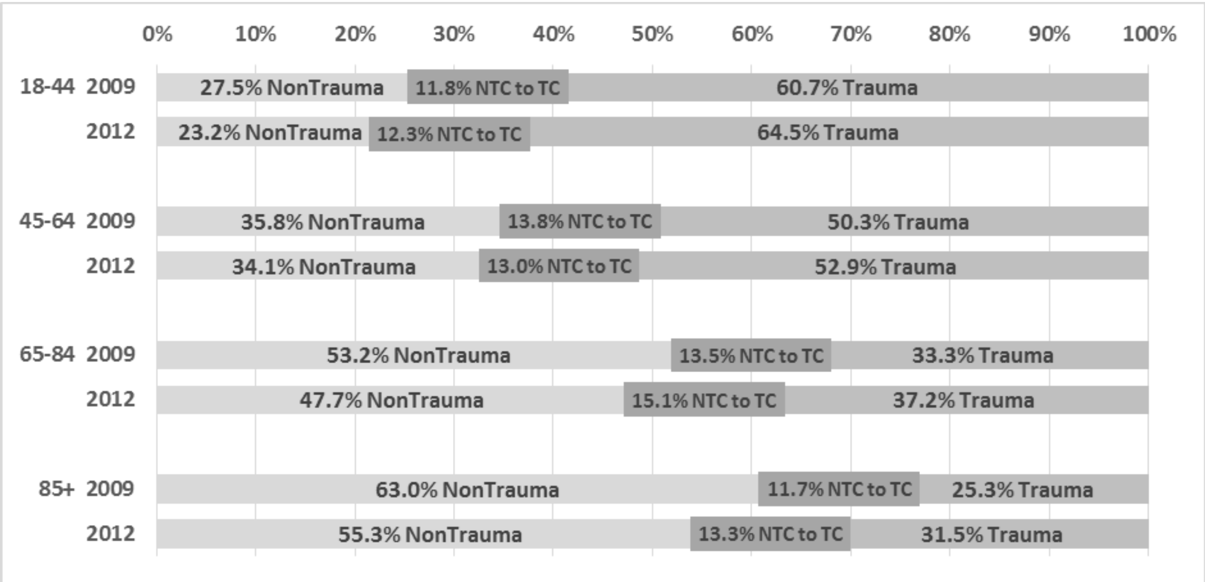

Figure 2. Observed Rates[a] of Initial Treatment and of Transfer to a Trauma Center after Initial Treatment at a Nontrauma Center (N = 52,757).

[a]Figure 2 presents the observed number of cases by initial treating emergency department designation and subsequent transfers from a non-trauma center from the 11 states with patient-level identifiers (N = 52,757). From 2009 to 2012 among 18–44 year olds initial trauma center treatment increased by 3.8%, whereas among those aged 85+ years it increased 6.2%, indicating a decrease in the age-based disparity.

APPENDIX

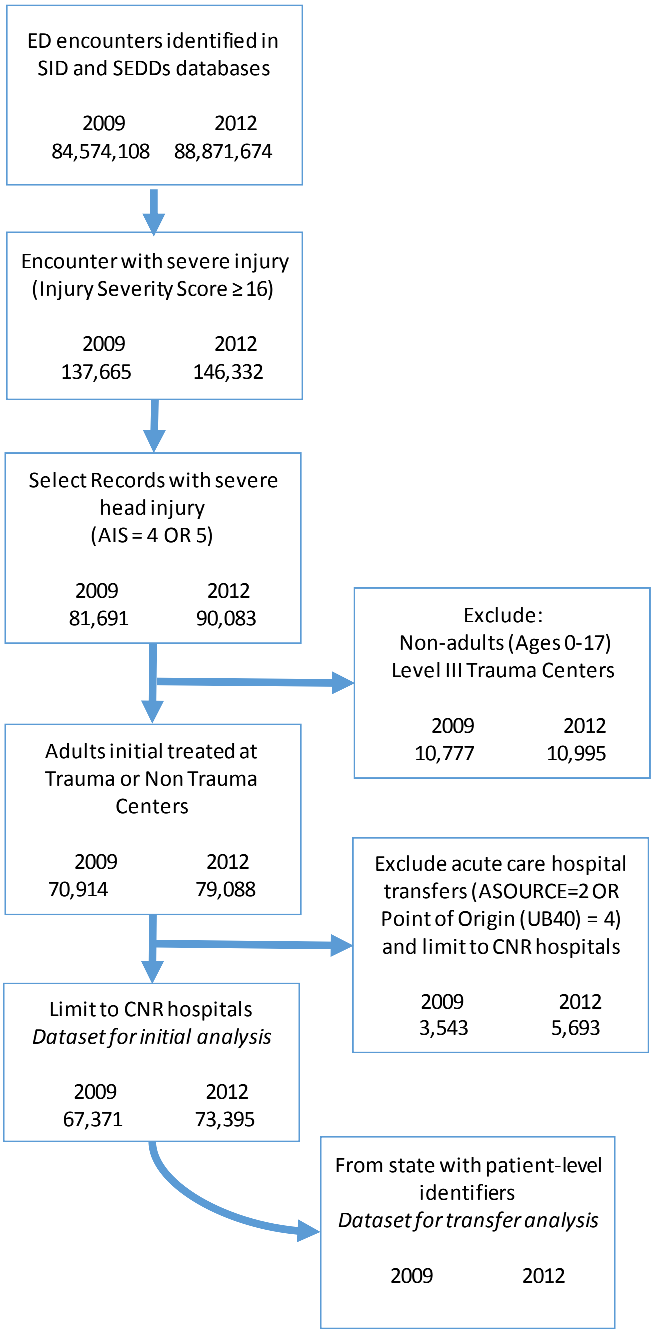

Figure 1: Identification of analytic cases: Severe trauma injuries ocuring during the years 2009 and 2012 and reported in the state emergency department databases (SEDDs) or state inpatient databases(SIDs) were identified. The sample was further limited to acute head injuries ocuring among adults and initially treated at either a trauma center (Level I/II) or non-trauma center.

CNR = Clinical Nonresidential; ED = emergency department.

Table A1

Variable	Odds Ratio of Admission	Odds Ratio of Transfer	Prevalence by Age Group in Years, %				
			Overall	18–44	45–64	65–84	85+
Number of comorbidities							
1	2.86*	0.67*	20.5	22.0	22.5	19.8	19.6
2	6.29*	0.36*	77.7	41.5	72.6	83.9	86.0
3+	17.62*	0.12*	37.9	9.1	32.2	43.7	44.3
Specific comorbidity							
Electrolyte disorders	2.77*	0.47*	17.3	8.1	16.1	18.4	20.2
Diabetes	0.63*	1.78*	16.6	2.4	14.0	21.7	16.1
Deficiency anemias	1.95*	0.42*	13.4	3.3	9.7	14.8	18.0
Chronic lung disease	1.15*	0.93	10.6	2.8	8.5	13.0	11.3
Hypothyroidism	1.66*	0.54*	10.2	0.9	4.7	11.5	15.7
Renal failure	0.86*	1.03	9.5	1.2	5.4	11.5	12.6
Alcohol abuse	0.97	1.16*	9.1	17.9	24.3	5.4	1.1
Congestive heart failure	1.05	1.13	8.5	0.4	2.7	9.7	13.9
Depression	1.71*	0.56*	7.4	2.8	7.5	8.0	8.3
Coagulopathy	1.37*	0.89	5.5	2.5	6.8	5.8	5.1
Paralysis	2.71*	0.34*	5.0	2.2	4.7	6.2	4.5

Estimated Odds of Transfer and Age-Group Specific Prevalence of Comorbidities

*Significant at 5% level.

Table A2

Summary of Length of Stay and Number of Comorbidities (CM)

Length of Stay (days)	Number of Cases	Average Number of Comorbidities(CM)	Percentage with 3+ CMs	Change in Average CM by Length of Stay
Treated and released	37,338	0.95	10.3	
1	18,339	1.57	23.3	0.62
2	13,943	2.11	35.3	1.16
3	12,917	2.46	44.3	1.51
4	10,324	2.60	47.5	1.65
5	8,095	2.74	50.8	1.79
6	6,270	2.90	54.1	1.95
7	4,983	3.04	57.7	2.09
8	3,920	3.20	60.5	2.24
9	3,101	3.21	59.5	2.26
10	2,537	3.19	60.8	2.23
11	2,122	3.27	60.8	2.31
12	1,693	3.35	62.8	2.40
13	1,487	3.30	62.6	2.35
14	1,247	3.44	64.4	2.49
15	1,166	3.40	63.9	2.45
16	947	3.37	64.5	2.42
17	903	3.32	60.7	2.37
18	770	3.36	62.3	2.40
19	761	3.35	61.4	2.40
20+	7,877	3.22	58.9	2.27

Table A3: Stepwise Regression Results concerning Age Disparities in the Odds of Initial Treatment at a Trauma Center for Adults With Severe Head Trauma (N = 140,766)

	Model 1 Year and Age Group Only			Model 2* Plus Demographics			Model 3† Plus Injury Covariates			Model 4‡ Plus Other Clinical Complexity Covariates			Model 5§ *Table 2 of Manuscript*		
Year/Age Group	OR	Lower	Upper	OR	Lower	Upper	OR	Lower	Upper	OR	Lower	Upper	OR	Lower	Upper
Odds of Initial Treatment at Trauma vs Nontrauma Center Hospital, 2009 and 2012															
2009 (Ref=18–44)															
45–64	0.70	0.67	0.74	0.71	0.68	0.75	0.89	0.85	0.94	0.75	0.71	0.79	0.76	0.71	0.81
65–84	0.41	0.39	0.43	0.52	0.50	0.55	0.67	0.64	0.71	0.56	0.53	0.59	0.61	0.56	0.65
85+	0.33	0.31	0.34	0.42	0.40	0.45	0.56	0.53	0.59	0.46	0.44	0.49	0.53	0.49	0.57
2012 (Ref=18–44)															
45–64	0.67	0.64	0.70	0.69	0.66	0.73	0.86	0.82	0.91	0.72	0.68	0.76	0.74	0.69	0.80
65–84	0.40	0.38	0.42	0.51	0.48	0.54	0.65	0.61	0.68	0.55	0.52	0.58	0.59	0.54	0.63
85+	0.34	0.32	0.35	0.44	0.42	0.47	0.58	0.55	0.61	0.49	0.46	0.53	0.56	0.51	0.60
Change in Odds of Initial Treatment at Trauma Center Within Each Age Group Between 2012 and 2009															
2012 vs. 2009‖															
18–44	1.11	1.05	1.17	1.09	1.04	1.15	1.12	1.06	1.18	1.09	1.03	1.15	1.12	1.04	1.20
45–64	1.06	1.01	1.11	1.06	1.01	1.11	1.08	1.03	1.13	1.04	1.00	1.10	1.10	1.03	1.16
65–84	1.07	1.04	1.11	1.07	1.03	1.11	1.08	1.04	1.12	1.06	1.03	1.10	1.08	1.03	1.13
85+	1.14	1.09	1.20	1.15	1.10	1.20	1.16	1.10	1.22	1.16	1.10	1.22	1.18	1.11	1.25
Gen. R^2	*0.05*			*0.08*			*0.15*			*0.19*			*0.56*		

Gen. R^2 = generalized R squared; lower = lower limit of 95% confidence interval, OR = odds ratio, Ref = reference, Upper = upper limit of 95% confidence interval.

* Model 2 added demographic covariates: sex (p<.001), location of residence (p<.001), and expected payer (p<.004).

† Model 3 added injury covariates: location of accident ($p<.001$); type of accident; injury severity score; number of secondary diagnoses; and indicators for intracranial, spinal, and fracture-related injury.

‡ Model 4 added other clinical complexity covariates: number of comorbidities and specific indicators for hypertension, electrolyte disorders, neurologic disorders, diabetes, alcohol abuse, deficiency anemias, pulmonary disease, hypothyroidism, congestive heart failure, depression, renal failure, coagulopthy, and paralysis.

§ Model 5 added hospital and area-level covariates: hospital region, bed size, ownership, and number of Level I and Level II trauma centers within 5, 15, and 30 miles of initial treating emergency department.

‖ For each age group, the change in odds of initial treatment at a trauma center in 2012 compared with 2009 were computed at the sample wide average or prevalence of all other covariates included in the model. Table 1 lists these values.

Caption: The unadjusted model, Model 1, which considered only year and age, indicated significant age disparities in both 2009 and 2012. The likelihood of initial TC treatment increased over time for all age groups. The largest increase was among those in the 85-years-and-older age group (OR = 1.14), and the second largest was among those in the 18–44-year age group (OR = 1.11), with the oldest age group experiencing a significantly larger increase ($p = .047$). These disparities and trends persisted after adjustment for demographics, case complexity, medical complexity, and area-level factors.