SPECIAL ARTICLE

A National Evaluation of the Effect of Trauma-Center Care on Mortality

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ABSTRACT

BACKGROUND

Hospitals have difficulty justifying the expense of maintaining trauma centers without strong evidence of their effectiveness. To address this gap, we examined differences in mortality between level 1 trauma centers and hospitals without a trauma center (non–trauma centers).

METHODS

Mortality outcomes were compared among patients treated in 18 hospitals with a level 1 trauma center and 51 hospitals non–trauma centers located in 14 states. Patients 18 to 84 years old with a moderate-to-severe injury were eligible. Complete data were obtained for 1104 patients who died in the hospital and 4087 patients who were discharged alive. We used propensity-score weighting to adjust for observable differences between patients treated at trauma centers and those treated at non–trauma centers.

RESULTS

After adjustment for differences in the case mix, the in-hospital mortality rate was significantly lower at trauma centers than at non–trauma centers (7.6 percent vs. 9.5 percent; relative risk, 0.80; 95 percent confidence interval, 0.66 to 0.98), as was the one-year mortality rate (10.4 percent vs. 13.8 percent; relative risk, 0.75; 95 percent confidence interval, 0.60 to 0.95). The effects of treatment at a trauma center varied according to the severity of injury, with evidence to suggest that differences in mortality rates were primarily confined to patients with more severe injuries.

CONCLUSIONS

Our findings show that the risk of death is significantly lower when care is provided in a trauma center than in a non–trauma center and argue for continued efforts at regionalization.

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In 1976, the American College of Surgeons Committee on Trauma published criteria for categorizing hospitals according to the resources required to provide various levels of care for traumatic injuries.[1] Increasingly, states are using these criteria as a basis for designating trauma centers as part of a regionalized approach to trauma care.[2] However, this process has not been uniform. There is substantial variation across states in the number and geographic distribution of trauma centers,[2-4] owing in part to the lack of strong evidence of the effectiveness of trauma centers coupled with high costs of verifying their capabilities.[5] The existing evidence is based on studies of preventable deaths involving subjective reviews and restricted inclusion criteria,[6] registry-based studies that rely on comparisons of the number of observed deaths in trauma centers with the number expected on the basis of national normative data,[7] or population studies limited by their use of administrative data and historical controls.[8,9] Furthermore, studies have focused on in-hospital mortality, yet a substantial proportion of patients with traumatic injuries die of their injuries in the year after discharge.[10,11] The National Study on the Costs and Outcomes of Trauma (NSCOT) was designed to address these limitations and identify differences in outcomes and costs associated with treatment at hospitals with a level 1 trauma center and hospitals without a trauma center (non–trauma centers). In this report, we examine the effect of care in a trauma center on the risk of death. We hypothesized that the risk of death would be lower at a trauma center as compared with a non–trauma center and that the effect would be largest for younger patients with more severe injuries.

METHODS

SETTING

The NSCOT was conducted in 15 regions defined according to contiguous Metropolitan Statistical Areas in 14 states (Table 1). The Metropolitan Statistical Areas were selected from among the 25 largest such areas in 19 states (Arizona, California, Colorado, Florida, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, New Jersey, New York, North Carolina, Oregon, Pennsylvania, South Carolina, Virginia, Washington, and Wisconsin) for which routinely collected hospital-discharge data were available in 1999. We excluded Metropolitan Statistical Areas in which large non–trauma centers collectively treated fewer than 75 patients with major trauma annually, as defined according to an Injury Severity Score of more than 15, on the basis of the diagnostic codes of the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM).[12,13]

Within each Metropolitan Statistical Area, we identified all level 1 trauma centers and large non–trauma centers (Table 1). Hospitals were identified as level 1 trauma centers if designated by a state or regional authority or verified by the American College of Surgeons Committee on Trauma. Large non–trauma centers were neither designated nor verified as trauma centers at any level and treated at least 25 patients with major trauma annually. Although virtually all non–trauma centers that met the study criteria were asked to participate (124 of 131), only a sample of trauma centers (27 of 68) was selected. This sample was devised to achieve approximately equal numbers of small, medium, and large centers on the basis of the annual volume of patients with major trauma. Eighteen (66.7 percent) of the trauma centers and 51 (40.8 percent) of the non–trauma centers agreed to participate and received approval from their institutional review board. The principal reason for nonparticipation among trauma centers was lack of approval by the institutional review board (7 of 9), whereas the majority of nonparticipating non–trauma centers (48 of 73) declined to participate because of a lack of administrative support to facilitate the study.

Non–trauma centers were, on average, smaller than trauma centers, were less likely to be members of the Council of Teaching Hospitals, and treated fewer patients with major trauma (Table 2). However, 17 such centers had a designated trauma team, and 8 of these had a trauma director. As compared with the universe of level 1 trauma centers and non–trauma centers located in Metropolitan Statistical Areas, the NSCOT sample consisted of larger hospitals that were more likely to be members of the Council of Teaching Hospitals.[2] During the study, one of the non–trauma centers was designated a level 1 trauma center and one level 1 trauma center lost its verification. For the analysis, these hospitals were categorized according to their status at enrollment.

Table 1. Number of Participating Trauma Centers and Non–Trauma Centers, According to Metropolitan Statistical Area.

Metropolitan Statistical Area	Level 1 Trauma Centers			Non–Trauma Centers		
	Met Criteria	Selected for Study	Enrolled in Study	Met Criteria	Selected for Study	Enrolled in Study
Boston; Providence, R.I., Fall River, Mass., and Warwick, R.I.	5	3	1	8	8	4
New York City	18	3	1	9	9	4
Philadelphia and N.J.; Allentown, Bethlehem, and Easton, Pa.; Reading, Pa.	8	3	2	12	12	2
Williamsport, Pa.; Scranton and Wilkes-Barre, Pa.; Pittsburgh	3	2	1	7	0	0
Baltimore; Washington, D.C., Maryland and Virginia, and West Virginia	3	2	2	5	5	5
Charlotte, N.C.; Gastonia, N.C., and Rock Hill, S.C.; Greensboro, Winston Salem, and High Point, N.C.; Fayetteville, N.C.	2	2	2	7	7	4
Miami; Ft. Lauderdale, Fla.	3	1	1	10	10	1
Chicago; Gary, Ind.	13	2	2	15	15	2
Detroit; Saginaw, Mich.	3	2	1	18	18	8
Evansville and Henderson, Ind.	0	0	0	3	3	2
Milwaukee and Waukesha, Wis.; Madison, Wis.; Racine, Wis.	2	1	1	6	6	4
San Diego, Calif.	1	1	1	3	3	3
San Francisco; Oakland, Calif.; Modesto, Calif.; Stockton, Calif.	1	1	1	10	10	3
Los Angeles and Long Beach, Calif.	5	3	1	15	15	6
Seattle, Bellevue, and Everett, Wash.	1	1	1	3	3	3
All regions	68	27	18	131	124	51

Table 2. Characteristics of Participating and Nonparticipating Hospitals According to Trauma Center Status.*

Characteristic	Trauma Centers		Non–Trauma Centers	
	Participating Trauma Centers (N=18)	All U.S. Level 1 Trauma Centers† (N=177)	Participating Hospitals (N=51)	All U.S. Hospitals† (N=1836)
Publicly owned (%)	44.4	34.4	3.9	11.3
Member of the Council of Teaching Hospitals (%)	100.0	75.7	15.7	5.4
Average no. of acute care beds	303.0	270.6	207.2	114.3
Average no. of ICU beds	41.9	33.9	19.1	12.2
Average no. of admissions/yr (all conditions)	23,018	14,339	16,672	8638
Average no. of admissions for major trauma/yr‡	319.2	NA	39.9	NA
Designated trauma team (%)	100.0	NA	34.0	NA
Trauma director (%)	100.0	NA	16.0	NA
Continuous in-house call for general surgery (%)	84.2	NA	30.0	NA
Continuous in-house call for neurosurgery (%)	42.1	NA	16.0	NA
Continuous in-house call for orthopedic surgery (%)	42.1	NA	16.0	NA

* ICU denotes intensive care unit, and NA not applicable.
† Only hospitals located in a Metropolitan Statistical Area were included.
‡ Major trauma was defined by an Injury Severity Score of more than 15.

PATIENT POPULATION AND SELECTION

Patients were eligible for the study if they were 18 to 84 years of age, arrived alive at a participating hospital, and were treated for a moderate-to-severe injury (defined by at least one injury with a score of at least 3 on the Abbreviated Injury Scale) between July 2001 and November 2002.[14] Patients who presented with no vital signs and were pronounced dead within 30 minutes after arrival were excluded, as were patients who delayed seeking treatment for more than 24 hours, patients 65 years of age or older with a first listed diagnosis of hip fracture, patients with major burns, patients who spoke neither English nor Spanish, non–U.S. residents, and patients who were incarcerated or homeless at the time of injury. The patients were selected and eligibility was determined in two stages (Fig. 1). First, administrative discharge records and emergency department logs were prospectively reviewed to identify patients with a principal ICD-9-CM diagnosis code of 800 to 959 (excluding those due to late effects, foreign bodies, complications, burns, and [among patients 65 years of age or older] hip fractures). We then used a computer program to map ICD-9-CM diagnoses to Abbreviated Injury Scale scores[13] to select patients with at least one diagnosis involving a score of at least 3 on the Abbreviated Injury Scale. A total of 18,198 patients met these initial eligibility criteria.

In the second stage, we selected all 1438 patients who had died in the hospital and a sample of 8021 patients who were discharged alive, stratified within hospitals according to age (18 to 64 years vs. 65 to 84 years), ICD-9-CM–derived Injury Severity Scores (15 or less vs. more than 15); and principal body region injured, hierarchically classified beginning with the head, arms and legs, and other regions. A quota sampling strategy was used with the goal of enrolling approximately 3000 patients who were 18 to 64 years of age and 1200 patients who were 65 to

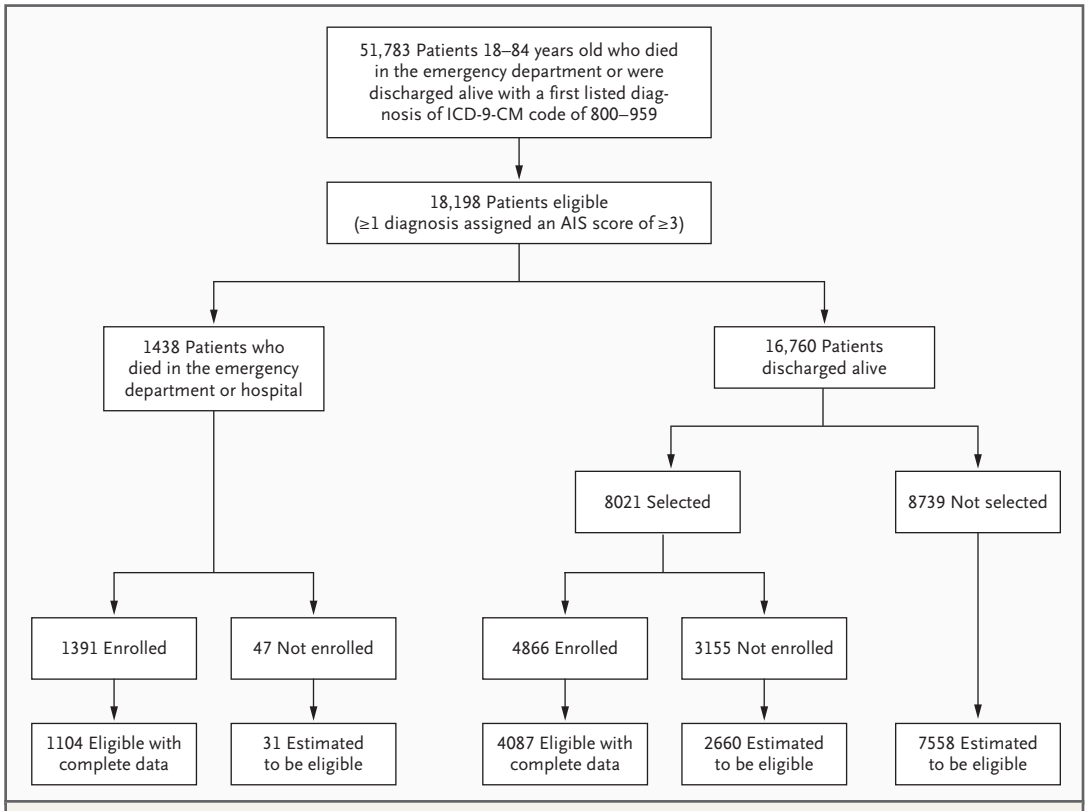

Figure 1. Approach to Enrollment.

The patients who were estimated to be eligible were determined according to sampling cell within hospitals, and the values were applied to the corresponding numbers of patients who were not enrolled or not selected. ICD-9-CM denotes *International Classification of Diseases, Ninth Revision, Clinical Modification*, and AIS Abbreviated Injury Scale.

84 years of age, evenly distributed across trauma centers and non–trauma centers and across categories of injury severity and principal region injured.

In stage 2, we reviewed patients' complete medical records to determine their final eligibility. Medical records were obtained for 1391 (96.7 percent) of the patients who died in the hospital. Of these, 287 were excluded, leaving 1104 eligible patients for whom medical-record data were abstracted. The most common reasons for exclusion in the second stage were death within 30 minutes after arrival and no vital signs (50.8 percent), lack of evidence of trauma (19.6 percent), and treatment sought more than 24 hours after injury (21.5 percent).

Patients discharged alive and selected for the study were contacted at 3 months by mail and then by telephone, and consent was obtained to access their medical records and interview them at 3 and 12 months. Of the 8021 such patients who were selected for the study, 4866 (60.7 percent) were enrolled, 1635 could not be located, 1177 declined to participate, and 343 completed the interview but never provided written permission for a review of their medical records. Of the 4866 who were enrolled, 779 (16.0 percent) were determined to be ineligible on review of their medical records, leaving 4087 eligible live patients for whom complete medical-record data were abstracted. The most common reasons for exclusion in stage 2 were treatment sought more than 24 hours after injury (70.8 percent) and a lack of evidence of trauma (25.4 percent).

For two reasons it was necessary to weight data on the 5191 eligible participants with complete medical-record data (1104 of whom died in the hospital and 4087 of whom were discharged alive) to the population of eligible patients. First, the sampling protocol selected all patients who died in the hospital but only a proportion of patients discharged alive. Second, not all patients selected for inclusion in the study were enrolled. The resulting "sampling" weights consist of the reciprocal product of two probabilities: the conditional probability of being selected and the probability of being enrolled and having data abstracted from the medical record, given that the patient was selected. The reference population to which inferences are made for the NSCOT consists of 15,440 patients who met or were projected to meet the inclusion criteria.

DEFINITION OF OUTCOMES AND DATA COLLECTION

Outcomes of interest included death in the hospital and death within 30, 90, and 365 days after injury. We identified deaths that occurred after discharge either by interviewing a proxy or through a match with the National Death Index.[15] To maximize the ascertainment of patients who died after being discharged, we searched the National Death Index 24 months after the last patient had been enrolled.

Characteristics of the patients and their injuries that were related to the risk of death were obtained from medical records and used in the analysis to adjust for differences between those treated at trauma centers and those treated at non–trauma centers. Nurses, trained specifically for the NSCOT and certified in scoring of the Abbreviated Injury Scale by the Association for the Advancement of Automotive Medicine, abstracted data from the patients' medical records.

Patients were characterized on the basis of their sociodemographic characteristics and preexisting medical conditions. Preexisting conditions were identified from a patient's medical record, and a score for the Charlson comorbidity index was derived.[16] The index is based on 17 indicators of coexisting conditions, which are weighted and then totaled to give a single value. A value of 0 indicates that there are no serious coexisting conditions. Since the Charlson comorbidity index does not include either obesity or coagulopathy, both of which correlate with the risk of death after trauma,[17,18] these conditions were included in the analysis as individual covariates. The use of alternative models in which the Charlson score was replaced with individual indicators of preexisting conditions yielded similar results.

Injuries were characterized on the basis of their mechanism, anatomical severity, and physiological effect. The anatomical severity of individual injuries was assessed with the use of the Abbreviated Injury Scale.[14] Scores derived manually from a review of the medical record were used in all analyses. A total of 381 patients (7.3 percent) who were selected on the basis of having a maximal score of at least 3 were reclassified as having a maximal score of less than 3 after a review of their medical records. These patients were kept in the analysis. Several summary measures of the overall severity of injury were derived from injury-specific Abbreviated Injury

Scales, including the Injury Severity Score,[12] the New Injury Severity Score,[19] the Anatomic Profile Score,[20] and the worst survival risk ratio, as defined by Meredith and colleagues.[21]

We used the first assessment of blood pressure and pupillary response in the emergency department and the first assessments of the motor score of the Glasgow Coma Scale[22] in the field and the emergency department to measure the degree of physiological derangement. In categorizing patients according to the motor score of the Glasgow Coma Scale, we separated patients who were pharmacologically paralyzed from those with a score of 1 who were not pharmacologically paralyzed.

STATISTICAL ANALYSIS

Excluded from the present analysis were 137 patients who were transferred to a participating hospital 24 hours or more after injury as well as 11 patients whose length of stay before transfer from a participating center was less than 24 hours. We included 1107 patients who were transferred to a participating hospital from another hospital within 24 hours after injury (880 within 6 hours). When the analysis was repeated excluding these 1107 patients, similar results were obtained.

We used multiple imputation techniques[23] to account for missing covariates. Data were missing for fewer than 5 percent of patients except for the categories of prehospital intubation (6.9 percent had data missing), the first score for the Glasgow Coma Scale (13.4 percent), and the score for the Glasgow Coma Scale obtained before hospitalization (30.9 percent). Ten imputed data sets were created. For each data set, robust standard errors were computed to account for clustering within hospitals. Across data sets, estimates and standard errors were computed with the use of Rubin's combining rules.[24]

All analyses were performed with the use of data weighted to the population of eligible patients. To adjust for observable differences between patients treated at trauma centers and those treated at non–trauma centers, we used the inverse probability of treatment weighting approach described by Robins and colleagues.[25] In this approach, data on each patient are further weighted according to the reciprocal of the conditional probability of receiving care at a trauma center given all demographic and injury characteristics listed in Table 3 together with relevant interaction terms. These "adjustment" weights, often referred to as propensity scores, serve to create an "adjusted population," which has two important characteristics: the receipt of care at a trauma center is not confounded by covariates, and the effect of care at a trauma center is the same in the adjusted population as it is in the original reference population. This method hinges on the correct specification of a model for the propensity score. To check the adequacy of this model, we evaluated the balance on covariates in the adjusted population.[26] We also trimmed the adjustment weights to reduce the effect of influential observations on the overall results. The degree of trimming was chosen to minimize mean squared error.[27]

RESULTS

As compared with patients treated in trauma centers, those treated in non–trauma centers were older; had more coexisting conditions; were more likely to be female, non-Hispanic white, and insured; and tended to have less severe injuries (Table 3). After further weighting according to propensity scores, the two groups of patients were similar (Table 3).

The observed (unadjusted) case fatality rate in the hospital was higher among patients treated at trauma centers than among patients treated at non–trauma centers (8.0 percent vs. 5.9 percent). An additional 3.1 percent of patients died after discharge, with a smaller percentage dying after discharge from a trauma center than after discharge from a non–trauma center (1.9 percent vs. 6.3 percent).

After adjustment for differences in the case mix, the risk of death within one year after injury was significantly lower when care was provided in a trauma center than when care was provided in a non–trauma center (10.4 percent vs. 13.8 percent; relative risk, 0.75; 95 percent confidence interval, 0.60 to 0.95) (Table 4). The relative reduction in risk was similar for in-hospital, 30-day, and 90-day mortality (Table 4). We assessed whether the relative risk of death in a trauma center as compared with a non–trauma center varied according to the overall severity of injury. We observed a significant interaction between the score for the Abbreviated Injury Scale and treatment at a trauma center with regard to in-hospital mortality (two-sided $P=0.02$ by a glob-

Table 3. Characteristics of the Patients and Their Injuries before and after Propensity-Score Adjustment.*

Characteristic	Unweighted No. of Patients	Death within 365 Days	Before Adjustment		After Adjustment	
			Trauma Centers	Non–Trauma Centers	Trauma Centers	Non–Trauma Centers
		weighted %	*percent distribution*			
Patients						
Age†						
<55 yr	3096	6.9	78.6	53.0	71.9	72.5
55–64 yr	559	10.8	9.6	16.1	11.0	11.1
65–74 yr	607	17.3	6.3	11.3	8.0	7.4
75–84 yr	781	32.2	5.5	20.6	9.0	9.0
Sex						
Male	3363	10.2	73.1	57.4	68.9	67.0
Female	1680	11.4	26.9	42.6	31.1	33.0
Race or ethnic group						
Non-Hispanic white	3245	11.4	55.7	71.6	59.7	58.1
Non-Hispanic nonwhite	1054	9.3	25.9	15.8	23.9	24.9
Hispanic	744	9.1	18.4	12.6	16.4	17.0
Health insurance before injury						
Medicare only	609	29.5	6.7	12.2	7.9	6.5
Medicare plus private insurance	958	21.6	8.4	23.9	12.8	12.7
Private insurance	1703	5.9	39.0	36.0	38.4	37.1
Medicaid	437	17.5	8.9	6.3	8.4	10.9
Other	206	3.4	4.2	5.2	4.2	5.9
None	1130	5.6	32.8	16.4	28.3	26.8
Charlson comorbidity index score‡						
0	3306	7.7	76.5	57.8	71.5	72.8
1	758	9.8	13.8	16.7	14.4	12.7
2	409	19.8	5.0	9.8	6.2	6.4
≥3	570	31.1	4.8	15.6	7.8	8.2
Obesity						
Yes	77	17.3	1.3	1.6	1.3	1.6
No	4966	10.5	98.7	98.4	98.7	98.4
Coagulopathy						
Yes	76	20.1	0.8	1.7	1.2	1.3
No	4967	10.4	99.2	98.3	98.8	98.7

al test for two-way interactions between the type of hospital and maximal scores), 30-day mortality (P=0.03), and 90-day mortality (P=0.02) but not 365-day mortality (P=0.61). As shown in Table 4, the relative risks of death among patients with a maximal score for the Abbreviated Injury Scale of 4 or a maximal score of 5 or 6 were lower than the risks among those with a maximal score of only 3. On the other hand, there were minimal differences in risk between patients with a maximal score of 4 and those with a maximal score of 5 or 6.

Although a formal test for an interaction between the type of hospital and age was not sig-

Table 3. (Continued.)

Characteristic	Unweighted No. of Patients	Death within 365 Days	Before Adjustment		After Adjustment	
			Trauma Centers	Non–Trauma Centers	Trauma Centers	Non–Trauma Centers
		weighted %	*percent distribution*			
Injuries						
Mechanism						
Blunt, motor vehicle	2190	8.0	53.2	31.9	48.2	49.9
Blunt, fall	1714	14.6	20.3	52.5	27.9	27.3
Blunt, other	512	9.8	9.5	9.5	9.9	8.5
Penetrating, firearm	475	14.3	11.9	4.2	9.7	10.3
Penetrating, other	152	5.1	5.0	1.9	4.3	3.9
First ED measurement of SBP <90 mm Hg						
Yes	304	32.2	4.3	3.2	4.1	5.3
No	4739	9.7	95.7	96.8	95.9	94.7
First ED assessment of pupils abnormal						
Yes	678	49.0	9.0	4.7	7.7	9.1
No	4365	7.4	91.0	95.3	92.3	90.9
First ED assessment of GCS motor score§						
6	3669	5.7	74.0	89.5	78.0	77.2
4–5	379	20.2	7.6	4.3	6.7	6.4
2–3	97	32.7	1.4	1.2	1.3	1.1
1, not chemically paralyzed	401	52.5	5.0	3.0	4.4	4.4
Chemically paralyzed	497	21.2	11.9	2.0	9.6	10.9
Field GCS motor score§						
6	3753	6.6	75.3	88.4	78.3	76.8
4–5	410	19.5	7.9	5.4	7.2	6.9
2–3	89	27.8	1.5	1.1	1.3	1.8
1, not chemically paralyzed	444	43.1	6.2	3.3	5.7	5.9
Chemically paralyzed	347	18.0	9.2	1.8	7.6	8.5
New Injury Severity Score¶						
<16	1460	5.9	22.5	52.3	30.0	30.2
16–24	1265	5.5	30.0	24.2	28.6	27.7
25–34	1270	10.6	29.0	15.0	25.6	23.6
>34	1048	28.6	18.5	8.5	15.8	18.5

nificant except with respect to the risk of death at 365 days (two-sided P=0.04, as compared with P=0.22 for in-hospital mortality, P=0.34 for 30-day mortality, and P=0.29 for 90-day mortality), the results suggest a larger effect of treatment at a trauma center among patients younger than 55 years of age (relative risks ranged from 0.61 to 0.68) than among those 55 years of age or older (relative risks ranged from 0.88 to 0.94).

DISCUSSION

Previous studies of the effectiveness of trauma centers have been inconclusive and hampered by

Table 3. (Continued.)

Characteristic	Unweighted No. of Patients	Death within 365 Days	Before Adjustment		After Adjustment	
			Trauma Centers	Non–Trauma Centers	Trauma Centers	Non–Trauma Centers
		weighted %	*percent distribution*			
Injury Severity Score‖						
<16	2121	4.8	40.7	66.1	47.0	46.4
16–24	1397	10.2	28.6	21.7	26.9	26.5
25–34	1110	20.9	21.8	9.7	18.8	18.1
>34	415	22.8	8.9	2.5	7.2	9.0
Anatomic Profile Score**						
<4.0	2495	4.9	50.2	69.0	54.8	54.8
4.0–4.9	505	6.2	12.2	7.3	11.1	10.3
5.0–5.9	804	13.8	14.9	12.9	14.4	13.2
6.0–6.9	550	21.6	10.0	6.0	8.8	10.2
≥7.0	689	30.7	12.7	4.8	10.9	11.5
Worst survival risk ratio††						
<0.25	194	71.0	2.0	0.9	1.8	2.3
0.25–0.49	568	35.4	8.6	4.8	7.6	8.0
0.50–0.74	590	15.1	13.5	5.8	11.5	10.7
0.75–0.89	2168	7.2	46.9	35.8	38.5	40.0
≥0.90	1523	5.1	29.0	52.7	40.6	39.0
Maximal AIS score, overall‡‡						
≤3	2744	4.9	57.5	73.0	60.9	60.4
4	1368	12.7	27.2	19.6	25.9	25.7
5–6	931	32.5	15.3	7.4	13.3	13.9
Maximal AIS score, head‡‡						
≤2	2988	5.8	63.2	72.0	65.2	63.5
3	526	7.3	11.0	9.2	11.0	12.3
4–6	1529	25.2	25.8	18.8	23.8	24.2
Midline shift						
Yes	505	52.1	6.1	4.6	5.7	5.6
No	4538	8.2	93.9	95.4	94.3	94.4
Open skull fracture						
Yes	160	27.8	2.8	1.3	2.4	2.0
No	4883	10.1	97.2	98.7	97.6	98.0

limitations in study design and reliance on in-hospital mortality as a measure. Most problematic has been the difficulty in adequately adjusting for referral bias — that is, the reality that trauma centers treat a higher proportion of young, severely injured patients, whereas non–trauma centers treat a higher proportion of elderly patients with coexisting conditions. We addressed this issue by stratifying the patients according to the type and severity of injury and age, collecting detailed information on important covariates known to influence the risk of death, and by us-

Table 3. (Continued.)

Characteristic	Unweighted No. of Patients	Death within 365 Days	Before Adjustment		After Adjustment	
			Trauma Centers	Non–Trauma Centers	Trauma Centers	Non–Trauma Centers
		weighted %	*percent distribution*			
Maximal AIS score, arms and legs‡‡						
0–1	2454	14.9	44.7	39.8	44.1	44.9
2	891	8.6	17.7	17.1	17.7	18.4
3–5	1698	6.7	37.6	43.1	38.1	36.7
≥2 Long-bone fractures or amputation						
Yes	347	8.4	8.7	5.0	7.7	8.0
No	4696	10.7	91.3	95.0	92.3	92.0
Maximal AIS score, abdomen‡						
≤2	4441	10.6	86.3	95.5	87.9	87.5
3	307	9.1	7.4	2.2	6.3	6.5
4–6	295	12.4	6.3	2.2	5.8	6.0
Maximal AIS score, thorax‡						
≤2	3375	11.4	62.3	78.2	65.6	64.6
3	1106	7.5	25.5	15.5	23.5	22.6
4–6	562	12.2	12.1	6.4	10.9	12.8
Flail chest						
Yes	85	15.3	1.9	0.9	1.6	1.8
No	4958	10.5	98.1	99.1	98.4	98.2
Any spinal cord injury						
Yes	191	10.8	4.8	1.6	4.0	5.0
No	4852	10.6	95.2	98.4	96.0	95.0
EMS level and intubation						
ALS, intubated	574	29.1	11.6	2.8	9.5	10.3
ALS, not intubated	2767	8.1	69.1	40.6	61.4	61.2
BLS	1024	11.0	11.3	34.6	16.8	16.7
Not transported by EMS	678	8.1	8.0	22.1	12.2	11.9

* ED denotes emergency department, SBP systolic blood pressure, EMS emergency medical services, ALS advanced life support, and BLS basic life support.
† The mean age of patients treated at trauma centers and patients treated at non–trauma centers was 45.4 years and 52.0 years, respectively, before adjustment and 43.2 years and 42.8 years, respectively, after adjustment.
‡ Scores for the Charlson comorbidity index can range from 0 (no serious coexisting conditions) to 17, with higher scores indicating a greater number of coexisting conditions.
§ Motor scores for the Glasgow Coma Scale (GCS) can range from 1 to 6, with higher numbers indicating better function.
¶ New Injury Severity Scores can range from 1 to 75, with higher scores indicating more severe injury.
‖ Injury Severity Scores can range from 1 to 75, with higher scores indicating more severe injury.
** An Anatomic Profile Score of more than 4 generally indicates more severe injury.
†† Worst Survival Risk Ratios range from 0 to 1, with higher scores indicating less severe injury.
‡‡ Scores for the Abbreviated Injury Scale (AIS) can range from 1 to 6, with higher scores indicating more severe injury.

ing propensity-score weighting to adjust for potential biases in the analysis.

After adjustment for differences in the case mix, the overall ris k of death was 25 percent lower when care was provided at a trauma center than when it was provided at a non–trauma center. Relative differences in risk, however, varied according to the severity of injury, with evidence to suggest that differences in the risk of death according to the type of hospital were primarily

Table 4. Adjusted Case Fatality Rates and Relative Risks of Death after Treatment in a Trauma Center as Compared with Treatment in a Non–Trauma Center.*

Variable	Weighted No. of Patients	Death in Hospital	Death within 30 Days after Injury	Death within 90 Days after Injury	Death within 365 Days after Injury
Overall population	15,009				
Trauma center (%)		7.6	7.6	8.7	10.4
Non–trauma center (%)		9.5	10.0	11.4	13.8
Relative risk (95% CI)		0.80 (0.66–0.98)	0.76 (0.58–1.00)	0.77 (0.60–0.98)	0.75 (0.60–0.95)
Age <55 yr	10,678				
Trauma center (%)		5.9	5.9	6.3	6.6
Non–trauma center (%)		9.0	8.7	9.2	10.8
Relative risk (95% CI)		0.66 (0.48–0.89)	0.68 (0.48–0.95)	0.68 (0.50–0.94)	0.61 (0.46–0.81)
Age ≥55 yr	4,331				
Trauma center (%)		12.3	12.4	15.6	20.7
Non–trauma center (%)		13.1	13.8	17.8	22.5
Relative risk (95% CI)		0.94 (0.56–1.61)	0.90 (0.56–1.44)	0.88 (0.60–1.27)	0.92 (0.67–1.28)
Maximal AIS score, ≤3	9,193				
Trauma center (%)		2.3	2.6	2.7	4.8
Non–trauma center (%)		1.6	1.9	3.3	5.5
Relative risk (95% CI)		1.44 (0.86–2.73)	1.36 (0.81–2.27)	1.24 (0.83–1.85)	0.89 (0.61–1.29)
Maximal AIS score, 4	3,847				
Trauma center (%)		8.3	8.4	9.9	12.3
Non–trauma center (%)		11.8	10.9	14.2	16.9
Relative risk (95% CI)		0.70 (0.49–1.02)	0.78 (0.56–1.08)	0.70 (0.52–0.93)	0.73 (0.55–0.97)
Maximal AIS score, 5–6	1,969				
Trauma center (%)		30.2	29.4	31.4	31.8
Non–trauma center (%)		43.2	43.9	44.4	44.4
Relative risk (95% CI)		0.70 (0.51–0.96)	0.67 (0.48–0.92)	0.71 (0.52–0.97)	0.72 (0.52–0.98)

* CI denotes confidence interval, and AIS Abbreviated Injury Scale.

among patients with Abbreviated Injury Scale scores of 4 or higher. Although there is insufficient evidence to establish a hospital-based effect among patients with scores of less than 4, the risk of death in this group of patients, especially among the young, is low. It is possible, however, that treatment at a trauma center could benefit these patients by reducing complications and overall treatment costs or improving functional outcomes and increasing the likelihood that they will return to productivity.

Differences in the risk of death according to the type of hospital also appeared to be greater among younger patients than older patients. Although the risk of death was lower among older patients treated at trauma centers than among those treated at non–trauma centers, the differences were not as large as those between younger patients and the relative risks of death were not significantly different from 1.0. An important limitation of our study, however, was the small number of older patients with severe injuries, resulting in wide confidence intervals for this cohort. This limitation may have contributed to our inability to detect a significant interaction between the type of hospital and age. Elderly patients with trauma represent a serious challenge, because they are at high risk for complications and death from injuries that would not necessarily prove fatal to their younger counterparts.[28-30] Paying more aggressive attention to coexisting medical conditions during the acute and post-acute phases may improve the outcome among such patients and is worthy of further study.[10,31-34]

Our estimates may be conservative for two reasons. First, we included only non–trauma centers that treated at least 25 patients with major trauma per year. Most non–trauma centers are small and may have a lower quality of trauma care than larger facilities. More important, 17 of the non–trauma centers in our study had a designated trauma team, and 8 of the 17 had a trauma director. Including these hospitals as non–trauma centers may have biased the results toward a more conservative estimate of the effect.

Caution is needed in generalizing our results. Because the NSCOT is a study of the effectiveness of trauma centers in urban and suburban America, our results cannot readily be extrapolated to rural areas of the country. In addition, we did not address the relative effectiveness of intermediate levels (2, 3, or 4) of trauma care. Finally, we excluded children and adolescents; the effect of care in a trauma center in this population must be addressed in a separate study.

Our results show that the overall risk of death is significantly lower when care is provided in a trauma center than when it is provided in a non–trauma center, and they argue for continued efforts at regionalization. At the same time, they highlight the difficulty in decreasing the risk of death among elderly patients with trauma.

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