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RESEARCH ARTICLE

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Comparison of survival outcomes among older adults with major trauma after trauma center versus non-trauma center care in the United States

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Abstract

Objective: To compare level 1 and 2 trauma centers with similarly sized non-trauma centers on survival after major trauma among older adults.

Data Sources and Study Setting: We used claims of 100% of 2012–2017 Medicare fee-for-service beneficiaries who received hospital care after major trauma.

Study Design: Survival differences were estimated after applying propensity-score-based overlap weights. Subgroup analyses were performed for ambulance-transported patients and by external cause. We assessed the roles of prehospital care, hospital quality, and volume.

Data Collection: Data were obtained from the Centers for Medicare and Medicaid Services.

Principal Findings: Thirty-day mortality was higher overall at level 1 versus non-trauma centers by 2.2 (95% confidence interval [CI]: 1.8, 2.6) percentage points (pp). Thirty-day mortality was higher at level 1 versus non-trauma centers by 2.3 (95% CI: 1.9, 2.8) pp for falls and 2.3 (95% CI: 0.2, 4.4) pp for motor vehicle crashes. Differences persisted at 1 year. Level 1 and 2 trauma centers had similar outcomes. Hospital quality and volume did not explain these differences. In the ambulance-transported subgroup, after adjusting for prehospital variables, no statistically significant differences remained.

Conclusions: Trauma centers may not provide longer survival than similarly sized non-trauma hospitals for severely injured older adults.

KEYWORDS
comparative effectiveness, injuries, Medicare, older adults, trauma centers

What is known on this topic

- Trauma experts have had a long-standing concern about inadequate limits on trauma center designations, which may affect hospital volumes and allow entry of lower quality facilities.

The research protocol was approved by a relevant institutional review board.

- Prior evaluations of trauma centers have generally produced favorable results but were conducted before 1999, for single regions, and relied on weak study designs.
- The most well-known study on the topic excluded individuals who died within 30 min of hospital arrival, a window during which an effective trauma team may make a difference.

What this study adds

- We used 100% of 2012–2017 Medicare beneficiaries and propensity-score-based balancing weights to compare outcomes after care at trauma centers versus non-trauma centers.
- We advanced the existing literature on trauma center comparative effectiveness in multiple ways, including by considering individuals who died shortly after hospital arrival.
- We found mortality for older adults with severe injuries may be higher at level 1 and 2 trauma centers than similarly sized non-trauma centers. These differences were not statistically significant among a subgroup of patients transported by ambulance who were balanced on pre-hospital characteristics.

1 | INTRODUCTION

Since at least the 1970s, when the American College of Surgeons Committee on Trauma (ACS-COT) published guidelines on treating injured patients, a central principle of planned trauma care has been regionalization, which requires considered limits on the number of trauma centers in a region.[1,2] The argument is that higher volume at fewer designated hospitals builds expertise that translates into higher quality of care. However, trauma experts have had a long-standing concern about inadequate limits on trauma center designations, which may affect hospital volumes and allow entry of lower quality facilities.[3–5] In fact, in both 2014 and 2021, ACS-COT warned that trauma center designation in most states did not meet population needs, potentially undermined quality of care, and was being shaped by business interests of “powerful health care institutions.”[6] It is important to ask: do trauma centers, as realized, produce better injury outcomes than non-trauma centers?

States designate hospitals as trauma centers based on criteria by ACS-COT for four levels: level 1 provide the highest level trauma care; level 2 supplement level 1 or provide the highest level trauma care in less-dense areas; levels 3 and 4 provide stabilization until transfer is possible.[1] Importantly, non-trauma centers are not hospitals below level 4 but are simply without any trauma center designation. In 2002, there were 190 level 1 and 263 level 2 trauma centers; in 2019, this increased to 218 and 332, respectively.[4,7] With each level, Medicare reimbursements increase and may include fees for trauma activation.[8]

Prior evaluations of trauma centers have generally produced favorable results but with important limitations. Most studies were conducted before 1999 for single regions and relied on weak study designs, including qualitative panel methods.[9–11] Since then, few studies have been conducted in the United States. In 2000, Nathens et al. found states had higher motor vehicle crash survival one decade after implementation of an organized trauma system.[12] Two more studies reported higher survival at level 1 versus level 2 trauma centers, however both relied on standard regression adjustment and only studied mortality in hospital.[13,14]

The most well-known study, by MacKenzie et al. compared level 1 trauma centers versus non-trauma centers and overcame many past challenges by collecting data from large metropolitan areas in the United States between 2001 and 2002, applying better statistical methods, and studying longer term outcomes.[15] For younger adults, it reported higher survival at level 1 trauma centers; for older adults, it found no differences. However, a limitation of this study was that it excluded individuals who died within 30 min of hospital arrival, a window during which an effective trauma team may make a difference.

We examined the association between survival and trauma center designation after major trauma using 2012–2017 Medicare claims. We improved upon the literature in multiple ways. First, we simultaneously compared level 1, level 2, and non-trauma centers on survival up to 1-year post-injury. Second, we included all individuals who received hospital treatment, thereby avoiding biases that might arise from only using patients who survived up to a time point. Third, we applied a newer approach to propensity-score-based weighting that mitigates problems with extreme weights.[15] Finally, owing to a large sample, we conducted multiple subgroup analyses.

2 | METHODS

2.1 | Data sources

We used hospital admission data from the Medicare Provider Analysis and Review (MedPAR) file and outpatient claims for 100% of 2012–2017 Medicare fee-for-service beneficiaries from nonrural counties. We used the Carrier file, which contains ambulance claims, for a 20% random sample of beneficiaries. Demographic information, validated death dates, and chronic conditions data were obtained from the Master Beneficiary Summary Files.

We obtained a trauma center registry from the American Trauma Society (ATS) for 2013–2017 and 2019, which included ACS-verified levels.[4,7] County-level demographic and health information was obtained from the Area Health Resources Files.[16]

2.2 | Identification of injuries

For identification of injuries, we dropped data from the last 3 months of 2015 to avoid any diagnosis coding irregularities during the transition from the International Classification of Diseases (ICD), Ninth Revision, Clinical Modification (ICD9-CM) to the Tenth Revision (ICD10-CM). Following the Healthcare Cost and Utilization Project (HCUP) approach,[17,18] we identified injuries by searching for ICD-9CM and ICD-10CM trauma diagnosis codes in the admitting (for inpatient claims), primary, and second diagnosis code fields in the hospital claims (see Data S1). We further flagged injuries with external cause codes in any diagnosis field associated with falls, motor vehicle crashes (MVCs), or firearms for subgroup analysis.

We required individuals to be enrolled in Medicare Parts A and B in the month of their injury. We only kept claims for the first hospital destination and not for subsequent hospital visits including transfers (see Data S1).

2.3 | Injury severity scoring

We created multiple measures of injury severity using the ICD Programs for Injury Categorization (ICDPIC) software,[19] which assigns an Abbreviated Injury Scale (AIS) score, ranging from one to six, to each injury in six body regions based on ICD diagnosis codes.[20] We summarized the AIS scores into injury severity scores (ISS), which are the sum of squares of the three highest AIS scores by body region, and new injury severity scores (NISS), which are the sum of squares of the three highest AIS scores regardless of body region.[21–26] We kept cases with NISS greater than 15, the standard rule for identifying major trauma. Further, to compare trauma centers with similarly sized non-trauma centers, we only kept observations from hospitals with at least 91 major trauma observations among Medicare beneficiaries per year, based on the trauma center volume distribution in our sample. The supplement considers alternative approaches to AIS scoring.

2.4 | Classification of trauma and non-trauma centers

We linked ATS data to the injury claims by CMS provider identification number and assigned the state-designated level to each linked hospital, except in the few cases of state versus ACS discrepancy in which case we assigned the ACS-verified level, and using the following year when information was missing. Non-trauma centers were hospitals without any linkage to the ATS data. We validated the trauma center level information in our dataset by manual review (see Data S1). Our final sample included level 1, level 2, and non-trauma centers. Figure 1 shows the distributions of trauma centers in 2019 across the United States.

2.5 | Identification of ambulance transports

For the 20% of the sample for which we had Carrier file claims, we linked the hospital claims with emergency ambulance claims by beneficiary identification number and service date to identify injuries that received prehospital care. Each ambulance claim contained the loaded miles, ambulance type (basic or advanced life support), and pickup location type.

2.6 | Other constructed measures

Since comorbid conditions can affect injury outcomes, we created measures of comorbidity for each patient. We calculated combined Charlson–Elixhauser comorbidity scores using diagnosis codes from all hospital claims within the year prior to the incident injury case.[27,28] We also created binary indicators for the presence of 29 chronic conditions, diagnosed at any point before the injury event.

To create measures of hospital quality, we developed risk-adjusted surgical survival scores for each hospital, using beneficiaries who received surgical services but did not overlap with our sample (see Data S1). We also measured volume by totaling the patients in our sample by hospital and year.

2.7 | Statistical analysis

We assessed death at 30, 90, 180, and 365 days after the injury event. We first compared unadjusted mortality by trauma center level in pairs (level 1 vs. non-trauma center, level 1 vs. level 2, and level 2 vs. non-trauma center). To adjust for potential confounding in these comparisons, we next constructed propensity-score-based overlap weights, which assign heavier weights to observations within each group that are more similar in characteristics (as summarized by the propensity score) to the comparison group.[29,30] In addition, this approach allowed us to balance groups prior to any outcomes analysis, a distinct advantage over regression analysis alone for reducing investigator bias.[31]

Specifically, using logistic regression, for each pair of comparisons, we modeled the propensity to receive care in the higher level trauma center (vs. the lower level or non-trauma center), conditional on demographic characteristics (age, race/ethnicity, sex, and dual eligibility for Medicare and Medicaid), injury severity (NISS, ISS, pints of furnished blood, and maximum AIS score by body region and overall), comorbid conditions (comorbidity score and indicators for 29 chronic conditions), several county demographic and health care characteristics (shown in Table 1), state, and year. The predicted probabilities or propensity scores, p, from this model were used to derive overlap weights. Each observation in the higher level trauma center was assigned a weight of $1 - p$ and each observation in the lower level or non-trauma center was assigned a weight of p. Finally, we used t-tests on weighted observations to estimate differences in outcomes between trauma center levels.

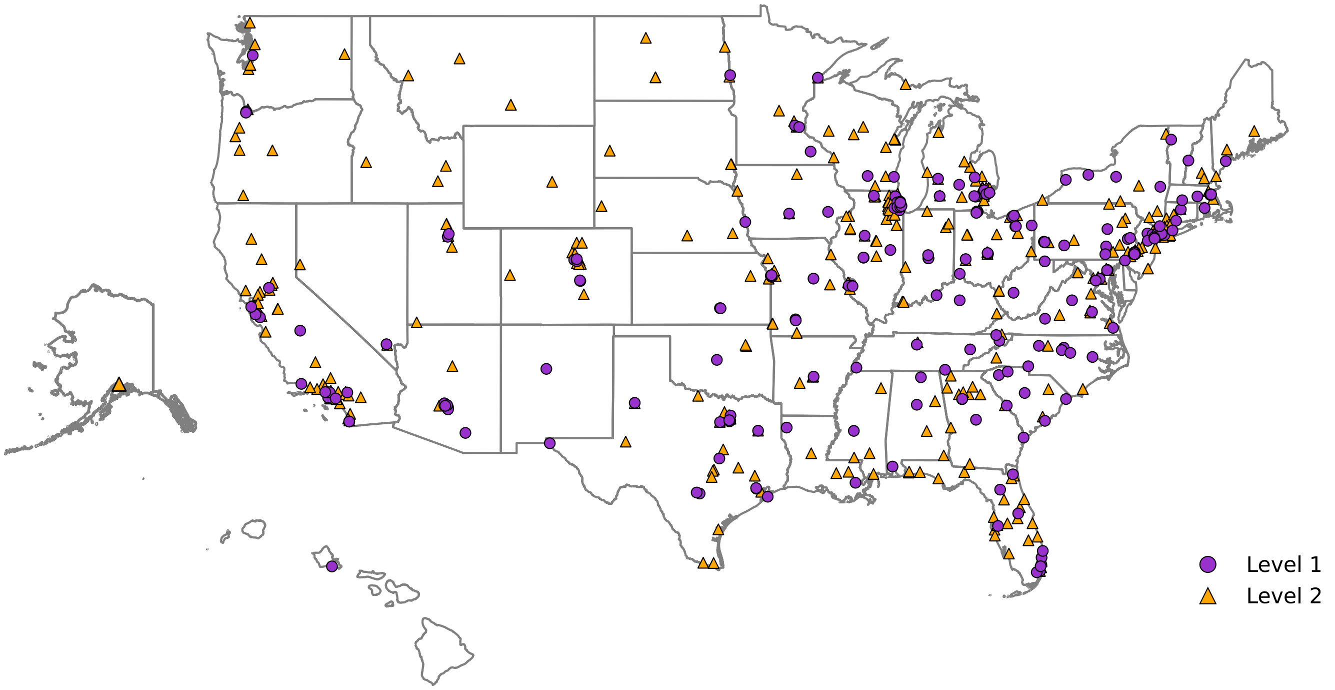

FIGURE 1 Distribution of level 1 and level 2 trauma centers in the United States. Data from a 2019 trauma registry certified by the American College of Surgeons and developed by the American Trauma Society were used to create this map. Level 1 trauma centers provide the highest level of trauma care in a region; level 2 trauma centers either supplement level 1 or provide the highest level trauma care in less-dense population areas.

We created subgroups by external cause and for ambulance-transported patients. Using the same approach as with the main analysis, we derived propensity-score-based weights based on subgroup-specific models and compared weighted observations between hospitals. For the ambulance subgroup, our model additionally included prehospital care variables.

Finally, we explored the roles of hospital surgical survival and volume, and prehospital care, in the associations between survival and trauma center designation (see Data S1). All statistical tests were conducted at an alpha level of 0.05. The supplement contains sensitivity analyses, including analysis with alternative weighting schemes, inclusion of lower volume hospitals, and estimation of E-values to assess sensitivity to potential confounding.

3 | RESULTS

3.1 | Patient characteristics

We identified 132,225 level 1, 108,539 level 2, and 71,990 non-trauma center patients with major trauma in our final sample (Table 1). Before adjustment, compared with non-trauma center patients, level 1 patients were more often male by 9.3 percentage points (pp), younger by 2.5 years, Black by 3.2 pp, and from poorer counties. Though they had fewer chronic conditions and lower comorbidity scores, their mean NISS were higher by 2.3 points. Level 2 patients were generally between those of level 1 and non-trauma centers. After propensity score-based weighting, no observable differences between comparison groups remained.

3.2 | All injuries

In unadjusted analyses, level 1 trauma centers had the highest and non-trauma centers had the lowest death rates for all injuries (4.0 pp [3.7, 4.3] higher 30-day mortality in level 1 vs. non-trauma center) (Table 2). In adjusted analyses, level 1 and level 2 trauma centers had similar death rates, but non-trauma centers had significantly lower death rates than both level 1 (by 2.2 pp [1.8, 2.6] 30 days post-injury) and level 2 (by 2.5 pp [2.1, 2.8] 30 days post-injury) trauma centers. Results were similar in direction at other time points. Also, results were robust to hospital clustered standard errors (see Data S1). Appendix Figure 3 displays the adjusted association between 30-day mortality and NISS. The parallel trends demonstrate injury severity scoring operated similarly across hospital types.

3.3 | Falls and MVCs

In unadjusted analyses, falls and MVCs had higher mortality at level 1 and level 2 trauma centers than non-trauma centers, though the difference was larger among MVCs (level 1 vs. non-trauma 30-day mortality: falls 4.2 pp [3.9, 4.6], MVCs 7.4 [5.2, 9.6]). After adjustment, mortality rates were still significantly higher at level 1 vs. non-trauma centers for falls (2.3 [1.9, 2.8]) and MVCs (2.3 [0.2, 4.4]). Differences persisted at

TABLE 1 Comparisons of patient characteristics by hospital type before versus after adjusting with propensity-score-based overlap weights.

	Before adjustment			After adjustment			Before adjustment			After adjustment		
Characteristics	Level 1[a]	Non-trauma[a]	SMD[b]	Level 1[a]	Non-trauma[a]	SMD[b]	Level 1[a]	Level 2[a]	SMD[b]	Level 1[a]	Level 2[a]	SMD[b]
Beneficiaries, n	132,225	71,990	-	132,225	71,990	-	132,225	108,539	-	132,225	108,539	-
Mean age, years	80.4	82.9	−0.31	82.0	82.0	−0.00	80.4	81.5	−0.13	81.0	81.0	0.00
Women, %	53.8	63.1	−0.19	59.6	59.6	−0.00	53.8	57.5	−0.07	55.8	55.8	0.00
Race, %												
White	83.1	86.2	−0.09	83.2	83.2	0.00	83.1	88.0	−0.14	85.9	85.9	0.00
Black	7.0	3.8	0.14	5.1	5.1	0.00	7.0	4.2	0.12	5.3	5.3	−0.00
Other[c]	1.0	0.8	0.01	1.0	1.0	0.00	1.0	0.9	0.01	0.9	0.9	0.00
Asian/PI	3.4	3.6	−0.01	4.2	4.2	−0.00	3.4	2.6	0.04	3.1	3.1	−0.00
Hispanic	5.5	5.6	−0.00	6.5	6.5	−0.00	5.5	4.2	0.06	4.8	4.8	−0.00
Mean number of chronic conditions	7.4	8.4	−0.20	8.1	8.1	−0.00	7.4	8.2	−0.15	7.9	7.9	−0.00
Chronic conditions, %												
1–6	41.8	33.1	0.18	36.1	35.9	0.00	41.8	35.3	0.13	37.8	37.7	0.00
≥7	58.2	66.9	−0.18	63.9	64.1	−0.00	58.2	64.7	−0.13	62.2	62.3	−0.00
Mean comorbidity score[d]	2.9	3.1	−0.07	3.0	3.0	−0.00	2.9	3.1	−0.05	3.0	3.0	−0.00
Comorbidity scores, %												
<1	25.6	22.6	0.07	24.2	23.9	0.00	25.6	23.6	0.05	24.5	24.5	0.00
1–3	39.2	39.1	0.00	38.8	38.9	−0.00	39.2	39.1	0.00	38.9	39.1	−0.00
≥4	35.2	38.2	−0.06	37.1	37.2	−0.00	35.2	37.3	−0.04	36.5	36.4	0.00
Mean new injury severity score[e]	21.4	19.1	0.38	19.7	19.7	−0.00	21.4	20.5	0.14	20.9	20.9	−0.00
New injury severity scores, %												
16–24	75.4	88.6	−0.35	84.4	84.4	0.00	75.4	80.4	−0.12	78.2	78.4	−0.00
25–40	21.0	10.6	0.29	14.3	14.3	0.00	21.0	17.3	0.09	19.1	18.9	0.01
≥40	3.6	0.8	0.19	1.3	1.3	−0.00	3.6	2.2	0.08	2.7	2.8	−0.00
Blood furnished to beneficiary, pints	0.1	0.0	0.04	0.0	0.0	−0.00	0.1	0.0	0.03	0.0	0.0	−0.00
Median household income, county level	60324.1	63342.3	−0.19	63260.7	62968.3	0.02	60324.1	61322.6	−0.06	61523.9	61563.8	−0.00
County, %[f]												
Below poverty line	13.8	13.0	0.16	13.5	13.5	0.00	13.8	13.2	0.12	13.3	13.3	−0.00
Female sex	51.1	51.2	−0.15	51.2	51.2	0.00	51.1	51.1	0.03	51.1	51.1	0.00
Age ≥65 years	15.0	16.4	−0.33	15.3	15.3	0.00	15.0	15.7	−0.18	15.3	15.3	0.00
Metropolitan[g]	98.3	99.8	−0.16	99.7	99.7	−0.00	98.3	99.0	−0.06	99.0	99.0	−0.00
Persons with ≥4 years of college	34.4	35.1	−0.07	35.6	35.6	−0.00	34.4	33.0	0.14	33.9	33.9	−0.00

(Continues)

TABLE 1 (Continued)

Characteristics	Before adjustment			After adjustment			Before adjustment			After adjustment		
	Level 1[a]	Non-trauma[a]	SMD[b]	Level 1[a]	Non-trauma[a]	SMD[b]	Level 1[a]	Level 2[a]	SMD[b]	Level 1[a]	Level 2[a]	SMD[b]
General practice physicians	11.7	9.7	0.25	9.7	9.7	0.00	11.7	12.9	−0.14	12.0	12.0	−0.00
Medical school affiliated hospital	47.2	43.7	0.12	47.8	47.8	−0.00	47.2	37.9	0.34	41.6	41.6	0.00

[a]Level 1 = level 1 trauma center; Non-trauma = hospitals without a trauma center designation; Level 2 = level 2 trauma center.
[b]Standardized mean difference compared with level 1.
[c]Other race category includes Native American and Alaskan Natives.
[d]Comorbidity scores were calculated using the combined Charlson–Elixhauser method.
[e]New injury severity scores were calculated as the sum of squares of the three highest Abbreviated Injury Scale scores.
[f]County characteristics are based on the beneficiary's home county as listed in the Master Beneficiary Summary File.
[g]Counties in the sample are either metropolitan or micropolitan. Metropolitan counties have ≥1 urbanized area with a population ≥50,000; micropolitan areas have ≥1 urban cluster with a population between ≥10,000 and <50,000.

other time points and between level 2 and non-trauma centers. However, level 1 and level 2 trauma centers were not statistically different.

3.4 | Firearms

Non-trauma centers had too few firearm injuries for analysis. Level 2 trauma centers had higher mortality than level 1 at all time points in adjusted analyses, though these differences were not statistically significant.

3.5 | Ambulance transports

Ambulances traveled on average 8.1 miles to level 1 and 7.7 miles to level 2 trauma centers, and 6.2 miles to non-trauma centers. Prior to adjustment, level 1 and level 2 trauma centers had higher mortality than non-trauma centers (30-day mortality: level 1 vs. non-trauma 5.9 [4.8, 7.1]; level 2 vs. non-trauma 4.6 [3.4, 5.8]), but after adjustment, differences across levels and time points were not statistically significant. The supplement shows estimates are larger without adjustment for prehospital care variables.

3.6 | Hospital quality and volume

The distributions of risk-adjusted surgical survival substantially overlapped between hospital types (Appendix Figure 4A). On average, non-trauma centers performed best; however, introducing this measure into the main analysis had little impact on the trauma center designation coefficient. Likewise, all hospital types had substantial overlap in volume, but this measure too had little explanatory value for the association between survival and trauma center designation (Appendix Figure 4B).

3.7 | Sensitivity analyses

Our results were robust to multiple sensitivity analyses (see Data S1). In particular, we estimated E-values, which measure how strong of an association a potential confounder would have to have with the treatment and outcome to nullify our results, conditional on the observed covariates. For example, we estimated that a potential confounder would have to have a risk ratio of at least 1.85-fold each with trauma level and 30-day mortality to explain away our observed association between these variables. For context, in similarly adjusted analyses, NISS above 41 versus 16–24 had 1.59 times higher 30-day mortality risk. For further context, we considered physiologic measures, which are unobserved, through a paper that compared mortality prediction by NISS with and without demographic and physiologic information.[32] Without the information, the authors estimated a C-statistic of 0.786; after adding age, sex, and physiologic information, the C-statistic was 16.5% higher at 0.916. Even without considering the added predictive value of age and sex, this increased our confidence that a confounder

TABLE 2 Unadjusted and adjusted[a] percentage point (PP) differences in mortality between hospitals, all injuries, and by subgroup.

Outcome	Differences in mortality between hospital types (reference group identified by parentheses)		
	Level 1 versus non-trauma (ref) PP (95% CI)	Level 1 vs. level 2 (ref) PP (95% CI)	Level 2 versus non-trauma (ref) PP (95% CI)
All injuries			
Sample			
Treatment	lvl 1: 132,225	lvl 1: 132,225	lvl 2: 108,539
Control	NT: 71,990	lvl 2: 108,539	NT: 71,990
Unadjusted outcome			
Death at 30 days	4.0 (3.7, 4.3)*	0.6 (0.3, 0.9)*	3.4 (3.1, 3.7)*
Death at 90 days	2.6 (2.3, 3.0)*	−0.2 (−0.5, 0.2)	2.8 (2.4, 3.2)*
Death at 180 days	1.8 (1.4, 2.2)*	−0.5 (−0.9, −0.2)*	2.3 (1.9, 2.8)*
Death at 365 days	0.7 (0.2, 1.1)*	−1.2 (−1.6, −0.8)*	1.8 (1.4, 2.3)*
Adjusted outcome			
Death at 30 days	2.2 (1.8, 2.6)*	0.1 (−0.2, 0.4)	2.5 (2.1, 2.8)*
Death at 90 days	1.8 (1.3, 2.2)*	−0.2 (−0.6, 0.1)	2.3 (1.8, 2.7)*
Death at 180 days	1.5 (1.0, 2.0)*	−0.3 (−0.7, 0.1)	2.2 (1.7, 2.6)*
Death at 365 days	1.2 (0.7, 1.8)*	−0.5 (−1.0, −0.0)*	2.0 (1.4, 2.6)*
Falls			
Sample			
Treatment	lvl 1: 89,113	lvl 1: 89,113	lvl 2: 81,490
Control	NT: 58,233	lvl 2: 81,490	NT: 58,233
Unadjusted outcome			
Death at 30 days	4.2 (3.9, 4.6)*	0.9 (0.6, 1.3)*	3.3 (2.9, 3.6)*
Death at 90 days	3.1 (2.7, 3.6)*	0.4 (−0.0, 0.8)	2.8 (2.4, 3.2)*
Death at 180 days	2.6 (2.1, 3.1)*	0.1 (−0.3, 0.6)	2.5 (2.0, 3.0)*
Death at 365 days	1.9 (1.4, 2.5)*	−0.3 (−0.8, 0.2)	2.3 (1.7, 2.8)*
Adjusted outcome			
Death at 30 days	2.3 (1.9, 2.8)*	0.1 (−0.3, 0.5)	2.2 (1.8, 2.6)*
Death at 90 days	1.8 (1.3, 2.4)*	−0.1 (−0.6, 0.3)	2.0 (1.5, 2.5)*
Death at 180 days	1.6 (1.0, 2.2)*	−0.2 (−0.7, 0.3)	1.9 (1.3, 2.5)*
Death at 365 days	1.5 (0.8, 2.2)*	−0.3 (−0.9, 0.2)	1.9 (1.2, 2.6)*
Motor vehicle crashes			
Sample			
Treatment	lvl 1: 14,950	lvl 1: 14,950	lvl 2: 7723
Control	NT: 1107	lvl 2: 7723	NT: 1107
Unadjusted outcome			
Death at 30 days	7.4 (5.2, 9.6)*	1.2 (0.2, 2.2)*	6.2 (4.0, 8.3)*
Death at 90 days	7.1 (4.8, 9.5)*	0.9 (−0.2, 1.9)	6.3 (3.9, 8.7)*
Death at 180 days	6.7 (4.1, 9.2)*	1.1 (−0.1, 2.2)	5.6 (3.0, 8.1)*
Death at 365 days	6.3 (3.4, 9.1)*	1.4 (0.1, 2.7)*	4.9 (2.1, 7.7)*
Adjusted outcome			
Death at 30 days	2.3 (0.2, 4.4)*	−0.1 (−1.2, 1.0)	2.8 (0.7, 4.8)*
Death at 90 days	3.1 (0.8, 5.4)*	−0.6 (−1.8, 0.6)	3.0 (0.6, 5.3)*
Death at 180 days	3.0 (0.4, 5.6)*	−0.3 (−1.6, 1.0)	2.3 (−0.3, 4.9)
Death at 365 days	3.3 (0.4, 6.2)*	−0.0 (−1.4, 1.4)	1.9 (−1.1, 4.9)

(Continues)

TABLE 2 (Continued)

Outcome	Differences in mortality between hospital types (reference group identified by parentheses)		
	Level 1 versus non-trauma (ref) PP (95% CI)	Level 1 vs. level 2 (ref) PP (95% CI)	Level 2 versus non-trauma (ref) PP (95% CI)
Firearm injuries			
Sample			
Treatment		lvl 1: 627	
Control		lvl 2: 348	
Unadjusted outcome			
Death at 30 days		−7.4 (−13.9, −0.9)*	
Death at 90 days		−6.6 (−13.2, −0.1)*	
Death at 180 days		−5.8 (−12.4, 0.9)	
Death at 365 days		−5.9 (−12.7, 1.0)	
Adjusted outcome			
Death at 30 days		−1.1 (−9.9, 7.7)	
Death at 90 days		−3.6 (−12.3, 5.2)	
Death at 180 days		−2.2 (−11.3, 6.8)	
Death at 365 days		−0.8 (−9.9, 8.4)	
Ambulance-transported			
Sample			
Treatment	lvl 1: 11,206	lvl 1: 11,206	lvl 2: 9677
Control	NT: 5735	lvl 2: 9677	NT: 5735
Unadjusted outcome			
Death at 30 days	5.9 (4.8, 7.1)*	1.3 (0.3, 2.4)*	4.6 (3.4, 5.8)*
Death at 90 days	4.5 (3.2, 5.9)*	0.3 (−0.9, 1.5)	4.2 (2.8, 5.6)*
Death at 180 days	3.5 (2.0, 5.0)*	0.1 (−1.2, 1.4)	3.4 (1.8, 4.9)*
Death at 365 days	2.2 (0.5, 3.9)*	−0.3 (−1.8, 1.2)	2.5 (0.7, 4.2)*
Adjusted outcome			
Death at 30 days	1.5 (−0.1, 3.0)	−0.2 (−1.3, 1.0)	1.0 (−0.4, 2.5)
Death at 90 days	1.0 (−0.7, 2.8)	−0.6 (−1.9, 0.8)	1.3 (−0.4, 3.0)
Death at 180 days	0.5 (−1.5, 2.5)	−0.6 (−2.1, 0.9)	0.9 (−1.1, 2.8)
Death at 365 days	0.1 (−2.2, 2.3)	−0.6 (−2.3, 1.0)	0.3 (−1.8, 2.5)

*$p < 0.05$ for a statistical test of the difference between hospital types. Values in red are statistically significant differences that favor the reference group (always set as the lower level trauma or non-trauma hospital in a comparison); values in blue are statistically significant differences that favor the nonreference group (always set as the higher level trauma center in a comparison); values in black are not statistically significant.[a]Estimates are adjusted by propensity-score-based overlap weights. The propensity score model included patient-level demographic characteristics (age, race/ethnicity, sex, and dual eligibility for Medicare and Medicaid), injury severity (NISS, ISS, pints of furnished blood, and the max AIS score for each body region, and the max overall AIS score), comorbid conditions (comorbidity score and indicators for 29 chronic conditions), and county-level demographic and health characteristics (metropolitan vs. micropolitan area, natural log of median household income, proportion below federal poverty line, proportion female, proportion above 65 years, proportion with ≥4 years of college, proportion of physicians who are general practitioners, and proportion of hospitals with a medical school affiliation), and state and year fixed effects. In the subgroup who took an emergency ambulance ride, we additionally adjusted for miles, ambulance type (advance or basic life support), and pickup/drop-off location types.

is unlikely to exist that shares an association with mortality, after controlling for NISS, that is larger than the adjusted association between NISS and mortality.

4 | DISCUSSION

We were unable to find longer survival among older adults with care at a trauma center versus a similarly sized non-trauma center. In fact, level 1 and level 2 trauma centers performed comparably to each other but significantly worse than non-trauma centers. These findings persisted in the falls and MVCs subgroups. We were unable to adequately assess penetrating wounds in part due to the infrequent occurrence of such injuries in this population. Based on these results, older adults with major trauma may have higher chances of survival at larger non-trauma hospitals than trauma centers.

Despite using different samples and methods, our results are consistent with MacKenzie et al. one of the largest evaluations of trauma centers, in that neither study was able to establish a trauma center benefit for older adults.[15] Our findings share the direction of a recent paper that concluded older adults may not benefit from trauma center care; however, this study had limitations including the combining of level 4 and non-trauma centers and inadequate injury severity adjustment.[33] However, our findings contrast with the broader literature that has mostly identified benefits from trauma center care, albeit based on analysis of younger adults too.[9–14] Many of these studies were conducted over two decades ago, assessed regional systems, and/or applied weak study designs. In a recent analysis of Oklahoma, level 1 and 2 trauma centers had higher in-hospital survival than more rural level 3 and 4 trauma centers, but this study did not include non-trauma hospitals.[34] Two additional studies used instrumental variables and reported higher mortality at non-trauma centers than trauma centers.[35,36] However, the lack of regional- and patient-level covariates in both papers is a serious threat to the exclusion restriction of the instrumental variables analysis.[37]

Why might injured patients at trauma centers have lower survival than comparable patients at similarly sized non-trauma centers? We considered a few hypotheses. First, we explored differences in care quality as measured by surgical survival among nonoverlapping patients at each hospital. Non-trauma centers substantially overlapped in this measure with trauma centers and had significantly higher average 30-day surgical survival than level 2 trauma centers. Though this relationship could not explain our main findings, it challenges the assumption that trauma centers necessarily provide better care than non-trauma hospitals. Next, we considered patient volume, which has a considerable though mixed literature.[38–44] Here too, we found substantial overlap in the distribution of volume across hospitals and little explanatory value for our main findings.

Finally, we assessed differences in prehospital care in the ambulance-transported sample, motivated by research that indicates trauma outcomes are worse with advanced than basic life support[45,46] and by the longer average distance traveled to a trauma center in our sample. The ambulance sample exhibited smaller differences in survival between trauma centers and non-trauma hospitals than the overall sample. It may be that among ambulance-transported patients, trauma centers and large non-trauma hospitals have similar outcomes for older adults. After adjusting for prehospital variables, survival differences were further reduced and not statistically significant at any time point. Thus, under similar prehospital conditions, trauma centers and large non-trauma hospitals may perform even more similarly, suggesting that trauma centers may appear to have worse outcomes because they require longer transport distances and disproportionately receive advanced life support ambulances. This needs further investigation.

We did not investigate whether trauma center care may be more intensive than is beneficial for older adults. Our study has other limitations. We did not include individuals who died en route to a hospital and therefore did not fully consider the effects of longer travel to hospitals. Also, with the exception of the ambulance-transported subgroup, patients were not balanced on prehospital variables. More generally, our methods could not address unobserved differences between patients at different hospitals. The biggest source of such confounding may be residual differences in injury severity. However, similar methods for measuring severity are widely used, including in studies with medical records.[15,35,41,45] Our results were also robust to alternative scoring algorithms. We were not able to observe physiological characteristics or the geographic locations of injury events. However, our E-value analysis suggests including unobserved sources of confounding in our models, could we observe these, would be unlikely to nullify our results. Finally, we cannot generalize to smaller hospitals or younger adults.

The U.S. Centers for Disease Control and Prevention and ACS-COT direct major trauma patients to the highest level trauma centers within local systems.[47] Our study assessed trauma center designation as it has developed, which may not be as originally envisioned by trauma experts.[2–6] Given our observed survival differences, trauma centers may not provide better outcomes than large non-trauma hospitals for most injuries in the Medicare population.

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CONFLICT OF INTEREST STATEMENT

We have no potential conflicts of interest relevant to this article.

DATA AVAILABILITY STATEMENT

Our data were obtained from the Centers for Medicare and Medicaid Services under a data use agreement. We can share aggregated data as long as they meet the requirements of the data use agreement.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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