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Differences in trauma mortality between ACS-verified and state-designated trauma centers in the US

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ABSTRACT

Background: Traumatic injury is a leading cause of deaths worldwide, and designated trauma centers are crucial to preventing these. In the US, trauma centers can be designated as level I-IV by states and/or the American College of Surgeons (ACS), reflecting the resources available for care. We examined whether state- and ACS-verified facilities of the same level (I-IV) had differences in mortality, complications, and disposition, and whether differences varied by center level.

Materials and methods: Using all admissions reported to the National Trauma Data Bank 2010–2015, we estimated risk ratios for the association between current ACS verification (vs. state designation) and patient mortality and complications, adjusting for trauma level and facility, injury, and demographic characteristics. We tested the interaction between trauma level and ACS verification, stratifying by trauma level in the presence of significant statistical interaction.

Results: Overall, patients admitted to ACS-verified vs state-designated facilities had similar adjusted mortality risk [RR 1.00; 95% CI 0.91–1.03] and lower risk of discharge to intermediate care facilities [RR 0.58; 95% CI 0.44 to 0.78]. However, Level III and IV facilities had lower adjusted mortality risk when ACS-verified, with much lower mortality risk in ACS-verified Level IV facilities [RR 0.25; 95% CI 0.12 to 0.54].

Discussion: Findings suggest that while outcomes are similar between ACS-verified and state-designated Level I and II centers, state-designated Level III and particularly Level IV centers show poorer outcomes relative to their ACS-verified counterparts. Further research could explore mechanisms for these differences, or inform potential changes to state designation processes for lower-level centers.

Introduction

Trauma is a leading cause of death worldwide, with injuries accounting for 10% of the world's deaths [1]. In the US, as in many other industrialized countries, designated trauma centers are a key element in providing care to these individuals. Trauma centers can be designated at various levels (I–IV) reflecting the resources available for care at that institution, and together form a trauma system in which various levels collaborate to make the best use of medical resources [2].

While states or other appropriate geopolitical entities are empowered to designate trauma centers, the American College of Surgeons (ACS) has since 1987 offered an optional program to verify that a facility is performing as a trauma center and meets the criteria for each level, detailed in *Resources for Optimal Care of the Injured Patient* [2–4]. Depending on individual state requirements, a center can be state-designated at a particular level, without having received ACS verification for that level. ACS verification allows a hospital to demonstrate the quality of its trauma care, attracting patients and staff. At the same time, the ACS verification process may be resource-intensive in terms of staff time for preparation, mock surveys or external peer review, and implementation and maintenance of all ACS requirements. Requirements for state designation are typically based on the ACS guidelines, however, some requirements—including frequency and structure of site visits—may differ by state. Some states may add additional criteria, for example, Pennsylvania requires access to a helipad or designated helicopter landing area [5], or choose less stringent criteria than the ACS standards, such as reducing the research requirements for Level I centers [6] or not requiring that physicians be dedicated to a single hospital while on call for Levels II and III centers [6]. Of note, many states have less stringent verification requirements for Level IV trauma centers as compared

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with other levels—for example, Alaska requires ACS verification for Levels I-III [7], but not IV, Alabama only designates Levels I-III [6], and Colorado states that Level IV centers may define their scope of care and transfer patients when appropriate [8].

Most studies examining the relationship between trauma center level and patient outcomes have found better outcomes at Level I and II trauma centers as compared with lower-level facilities [9–11], but fewer studies have examined the impact of ACS verification as compared with state trauma center designation on patient outcomes. In single center studies, undergoing the ACS verification process was associated with improvements in nursing care, inpatient care, and patient management [12], along with reduced length of stay and severity-adjusted mortality and costs [13].

Findings from cross-center comparisons appear to be more equivocal, however. One study comparing ACS-verified and state-designated Level I and II centers using data from the ACS's National Trauma Data Bank (NTDB) 2007 to 2008 found that ACS verification predicted survival in Level II, but not Level I centers [14]. Another study, using earlier NTDB data (2002 to 2006), found no difference in overall mortality, although it noted a survival benefit for acute respiratory distress syndrome (ARDS) patients at ACS-verified centers as compared with state-designated centers [15].

The impact of ACS verification as compared with state designation has several important implications. It can indicate the extent to which the state-designated centers produce outcomes that are aligned with ACS-verified centers, which may influence the design of the state designation process. From a research perspective, the results can inform classification of centers in other NTDB studies, by elucidating the appropriateness of combining state- and ACS-verified centers of the same level into a single category. Finally, results from such studies can inform individual hospitals' decisions regarding pursuit of ACS verification.

Our study seeks to expand on previous literature regarding the impact of ACS verification as compared with state designation, in order to provide an updated and more complete picture of the impact of ACS verification on patient outcomes. Our study uses updated NTDB data (2010–2015) to examine differences in outcomes between ACS-verified and state-designated centers, and to compare outcomes at all four verification levels, rather than limiting analysis to levels I and II. Our primary research question was whether ACS-verified facilities had differences in mortality, common complications (those found most frequently in the dataset overall), and discharge disposition compared to state-designated facilities of the same level, and whether these differences varied by stratification of highest level of verification (state or ACS).

Materials and methods

The NTDB is the largest national trauma registry, with hospital admissions related to trauma submitted by approximately 700 voluntary facilities per year [12]. The NTDB collects patient characteristics, including injury characteristics, procedures, comorbidities, complications, demographics, and facility characteristics including ACS verification or state designation level.

We selected all admissions reported to the NTDB from 2010 to 2015, excluding patients under 18 years old, as our goal was not to evaluate pediatric verification. The primary outcome was mortality, and secondary outcomes were ICU admission, hospital disposition, unplanned intubation, unplanned return to the ICU, and unplanned return to the operating room (OR). It has previously been noted that some NTDB centers do not report any complications [13]; therefore, for all analyses of unplanned intubation and return to the OR, which are recorded as complications in the NTDB, we excluded centers reporting zero complications. The primary exposure was ACS verification, compared to state designation or no designation. Because some facilities submitted admission for multiple years and may have changed verification status, we used the current verification status for the admission year, meaning facilities could contribute as both verified and non-verified facilities. In the case of patients who transferred between facilities, patients were evaluated within the facility to which they were transferred.

Of particular interest was whether ACS-verified facilities had differences in outcomes compared to state designated facilities of the same level, and whether these differences varied within strata of highest level of verification (state or ACS). The causal pathway of interest was direct changes as a result of the ACS verification process to staff, staff training, and/or workflow, rather than by changes to patient composition.

Based on a review of existing literature regarding the NTDB [14,15] and the topic of interest [11,16,17], we considered potential confounders to be region of the US, hospital bed size, area-level socioeconomic status (SES), which we represented by payer mix (percent Medicaid, percent privately insured), and the proportion of burn cases reported. A possible mediator, but not along the pathway of interest, was the composition of patients represented in the facility, represented by gender, race/ethnicity, age, Charlson comorbidity index (CCI), injury severity score (ISS), drug or alcohol use, location of injury (home or residential institution, industry, farm, recreation, street, or other/unspecified), work-relatedness of injury, and whether the patient was transferred in.

Statistical analysis

Analysis focused on estimating risk ratios for ACS verification vs. non-verification, for which we used log-binomial generalized linear models (GLMs). Data in the NTDB are clustered by facility, therefore we estimated standard errors using the Huber-White or "sandwich" method for clustered data [18]. To allow nonlinearities of ISS, age, and Charlson comorbidity index, we included natural cubic splines for these variables in each model with one, two, and two knots respectively, determined by visually plotting mortality probability against each variable.

For each outcome, we fit crude models, models adjusted only for facility characteristics (including highest level of verification), and models adjusted for both facility and patient characteristics, to determine whether observed confounding was the result of facility characteristics or change in patient composition, or both.

To examine effect modification by level of designation, we also fit adjusted models with interaction terms for ACS verification by highest level of designation/verification (state or ACS). Here we excluded facilities less than level IV, as ACS verification only includes I-IV (state designation may include V). If p-values for interaction terms were less than 0.05, we estimated models stratified by highest level. For hospital disposition, some categories were not reported by all four levels of state or ACS verification – these included against medical advice (AMA), hospice, law enforcement, psychiatric hospital, and other institution. For consistency across all analyses, we only retained disposition categories present in at all levels, which included home without home care services, acute care, home with home care services, intermediate care facility, and rehab/nursing home.

Finally, there were 152 centers (14.9%) that became verified or changed level during the study period. To ensure this did not unduly influence our results, we conducted a sensitivity analysis in which we fit adjusted and stratified models to data excluding centers that became verified or changed level.

All statistical analyses were conducted in R version 3.4.2 for Windows, with Huber-White standard errors calculated using the

package "sandwich". IRB approval was not required for this study because the NTDB is a de-identified data set that does not contain information about identifiable human subjects.

Results

The 2010–2015 NTDB sample consists of 4,936,880 unique patient admissions due to trauma, with a final analytic sample of 4,044,449 remaining after excluding patients aged 17 or younger. Of these, 1,503,748 (37.2%) were female, with median [range] age 50 [18–116], and mean ± standard deviation (SD) Charlson comorbidity index 0.3 ± 0.8, and ISS 10.3 ± 9.1 (Table 1). Samples were submitted by 1023 separate facilities, of which 392 (38.3%) had any level of ACS verification, and 525 (51.3%) had a highest level of I or II (whether state or ACS). Overall, 115,829 (2.9%) patients died, 2,932,625 (72.9%) were admitted to an ICU, 9260 (0.2%) had an unplanned return to the OR, and 26,382 (0.7%) had an unplanned intubation (Table 2).

In crude analysis, patients admitted to ACS-verified facilities had greater mortality [RR 1.06; 95% CI 1.00–1.13; p = 0.044], ICU admission [RR 1.09; 95% CI 1.01–1.16; p = 0.023], unplanned return to OR [RR 1.16; 95% CI 0.95–1.42; p = 0.135], unplanned intubation [RR 1.30; 95% CI 1.10–1.53; p = 0.002], and were less likely to be discharged to an intermediate care facility [RR 0.51; 95% CI 0.38 to 0.68; p < 0.001], compared to home (Table 3).

However, after adjusting for facility characteristics, patients admitted to ACS facilities had similar risk of mortality [RR 1.01; 95% CI 0.96–1.06; p = 0.664], ICU admission [RR 1.01; 95% CI 0.95–1.08;

Table 2
Facility-level descriptive statistics.

	ACS-verified as of 2010		
	No	Yes	*P*-value
Total	631 (61.7%)	392 (38.3%)	
Hospital type (%)			<0.001
Community	250 (39.6%)	167 (42.6%)	
Non-Teaching	255 (40.4%)	107 (27.3%)	
University	126 (20.0%)	118 (30.1%)	
Highest designation/verification (%)			<0.001
I	103 (16.3%)	125 (31.9%)	
II	137 (21.7%)	160 (40.8%)	
III	164 (26.0%)	74 (18.9%)	
IV	67 (10.6%)	33 (8.4%)	
V or Undesignated	160 (25.4%)	0 (0.0%)	
Hospital size (# beds) (%)			<0.001
<=200	240 (38.0%)	93 (23.7%)	
> 600	71 (11.3%)	69 (17.6%)	
201 - 400	235 (37.2%)	130 (33.2%)	
401 - 600	85 (13.5%)	100 (25.5%)	
Geographic region of the US (%)			0.029
Midwest	177 (28.4%)	141 (36.0%)	
Northeast	81 (13.0%)	51 (13.0%)	
South	235 (37.7%)	116 (29.6%)	
West	131 (21.0%)	84 (21.4%)	

Table 1
Demographic and clinical patient characteristics.

		ACS Verified		
	Overall	No	Yes	*P*-value
Total	4,044,449	1,654,392 (40.9%)	2,390,057 (59.1%)	
Age, median (IQR)	50.0 (31.0–68.0)	51.0 (32.0–70.0)	49.0 (31.0–68.0)	<0.001
Gender=Male (%)	2,539,211 (62.8%)	1,018,914 (61.6%)	1,520,297 (63.6%)	<0.001
Race/ethnicity (%)				<0.001
American Indian	33,503 (0.9%)	7628 (0.5%)	25,875 (1.1%)	
Asian or Pacific Islander	75,476 (1.9%)	25,258 (1.6%)	50,218 (2.2%)	
Hispanic or Latino	409,518 (10.4%)	136,397 (8.5%)	273,121 (11.8%)	
Non-Hispanic Black	555,585 (14.1%)	258,469 (16.1%)	297,116 (12.8%)	
Non-Hispanic White	2,753,881 (70.1%)	1,138,979 (70.9%)	1,614,902 (69.5%)	
Other Non-Hispanic (including multi-racial)	101,012 (2.6%)	39,811 (2.5%)	61,201 (2.6%)	
Charlson comorbidity index, mean (SD)	0.3 (0.8)	0.3 (0.9)	0.3 (0.8)	<0.001
Injury Severity Score (ISS), mean (SD)	10.3 (9.1)	10.1 (8.9)	10.3 (9.1)	<0.001
Payer (%)				<0.001
Blue Cross/Blue Shield	188,973 (5.0%)	70,072 (4.5%)	118,901 (5.4%)	
Medicaid	405,604 (10.8%)	159,143 (10.1%)	246,461 (11.2%)	
Medicare	1,034,398 (27.4%)	451,247 (28.7%)	583,151 (26.5%)	
No Fault Automobile	219,743 (5.8%)	98,044 (6.2%)	121,699 (5.5%)	
Not Billed (for any reason)	26,184 (0.7%)	10,513 (0.7%)	15,671 (0.7%)	
Other	155,994 (4.1%)	82,029 (5.2%)	73,965 (3.4%)	
Other Government	115,118 (3.1%)	43,790 (2.8%)	71,328 (3.2%)	
Private/Commercial Insurance	883,985 (23.4%)	361,879 (23.0%)	522,106 (23.8%)	
Self Pay	630,790 (16.7%)	256,402 (16.3%)	374,388 (17.0%)	
Workers Compensation	110,070 (2.9%)	40,783 (2.6%)	69,287 (3.2%)	
Location of injury (%)				<0.001
Farm	26,927 (0.7%)	10,359 (0.6%)	16,568 (0.7%)	
Home	1,348,369 (34.5%)	565,175 (35.1%)	783,194 (34.1%)	
Industry	111,682 (2.9%)	42,284 (2.6%)	69,398 (3.0%)	
Mine	2,061 (0.1%)	732 (0.0%)	1329 (0.1%)	
Other/unspecified	474,791 (12.1%)	223,992 (13.9%)	250,799 (10.9%)	
Public Building	192,303 (4.9%)	73,037 (4.5%)	119,266 (5.2%)	
Recreation	151,760 (3.9%)	55,443 (3.4%)	96,317 (4.2%)	
Residential Institution	140,176 (3.6%)	59,970 (3.7%)	80,206 (3.5%)	
Street	1,460,752 (37.4%)	577,734 (35.9%)	883,018 (38.4%)	
Transfered from another facility=Yes (%)	945,604 (23.4%)	323,872 (19.6%)	621,732 (26.0%)	<0.001
Drug or alcohol use reported (%)	1,008,105 (24.9%)	357,759 (21.6%)	650,346 (27.2%)	<0.001

Table 3
Crude and adjusted risk ratios for ACS-verified vs. non-verified.

	Crude		Adjusted for facility characteristics[a]		Adjusted for facility and patient characteristics[b]	
	RR	95% CI	RR	95% CI	RR	95% CI
Mortality	1.06	1.00–1.13	1.01	0.96 to 1.06	1.00	0.95 to 1.04
ICU	1.09	1.01 to 1.16	1.01	0.95 to 1.08	0.97	0.91 to 1.03
Unplanned return to OR[c]	1.16	0.95 to 1.42	1.11	0.91 to 1.34	1.10	0.92 to 1.31
Unplanned Intubation[c]	1.30	1.10 to 1.53	1.34	1.13 to 1.59	1.30	1.11 to 1.52
Hospital Disposition (ref=Home)						
Acute care	0.93	0.77 to 1.13	0.98	0.84 to 1.14	0.98	0.84 to 1.14
Home w/ home care services	0.81	0.69 to 0.96	0.89	0.77 to 1.03	0.89	0.78 to 1.03
Intermediate care facility	0.51	0.38 to 0.68	0.59	0.44 to 0.78	0.58	0.44 to 0.78
Rehab nursing home	0.97	0.90 to 1.04	0.99	0.93 to 1.06	1.02	0.98 to 1.07

Abbreviations: ACS, American College of Surgeons; RR, risk ratio; CI, confidence interval; ICU, intensive care unit; OR, operating room.
[a] Facility characteristics adjusted for were region of the US, hospital bed size, percent burn admissions at facility, and payer mix (percent Medicaid, percent privately insured).
[b] Adjusted for facility characteristics as well as gender, race/ethnicity, age, Charlson comorbidity index, injury severity score (ISS), drug or alcohol use, location of injury (home or residential institution, industry, farm, recreation, street, or other/unspecified), whether the injury was work-related, and whether the patient was transferred from another facility.
[c] Analysis of complications excluded centers reporting zero complications.SOURCE: Authors analysis of data from the National Trauma Data Bank, 2010–2015.

p = 0.730], and unplanned return to OR [RR 1.11; 95% CI 0.91–1.34; p = 0.297], but still had greater risk of unplanned intubation [RR 1.34; 95% CI 1.13–1.59; p = 0.001] and lower risk of discharge to intermediate care facility [RR 0.59; 95% CI 0.44 to 0.78; p < 0.001] (Table 3).

Similarly, after adjusting for patient and facility characteristics, risk for patients in ACS-verified facility was similar for mortality [RR 1.00; 95% CI 0.95–1.04; p = 0.936], ICU admission [RR 0.97; 95% CI 0.91–1.03; p = 0.321], and unplanned return to OR [RR 1.10; 95% CI 0.92–1.31; p = 0.303], greater for unplanned intubation [RR 1.30; 95% CI 1.11–1.52; p = 0.001], and lower for discharge to intermediate care facility [RR 0.58; 95% CI 0.44 to 0.78; p < 0.001] (Table 3).

We further examined whether multiplicative interaction existed for ACS verification by highest level of verification, in models adjusted for patient and facility characteristics. We found that interaction was present with respect to mortality [p < 0.001], ICU admission [p < 0.001], and unplanned intubation [p < 0.001], but not for unplanned return to OR [p = 0.062]; interaction was also evident for each hospital disposition outcome [p < 0.001]. There was no difference in mortality for Level I [RR 1.00; 95% CI 0.95–1.06] or II [RR 1.04; 95% CI 0.98–1.10], but ACS verification was associated with lower mortality risk in Level III [RR 0.84; 95% CI 0.72 to 0.99] and much lower in Level IV [RR 0.25; 95% CI 0.12 to 0.54]. For ICU admission, ACS verification was associated with slightly greater risk for Level IV [RR 1.11; 95% CI 1.02–1.21], but not for other center levels. The greater risk of intubation associated with ACS verification appeared to only be present for Level I centers [RR 1.35; 95% CI 1.11–1.65]. For hospital disposition, ACS verification was associated with lower risk of discharge to another acute care center [RR 0.76; 95% CI 0.59 to 0.97] and to an intermediate care facility [RR 0.47; 95% CI 0.30 to 0.74] for Level I centers but not other levels, and lower risk of discharge to home w/ home care services for Level II but not other levels [RR 0.76; 95% CI 0.62 to 0.93] (Table 4).

Lastly, we conducted a sensitivity analysis excluding centers that became ACS verified or changed levels during the course of the study period, and again fit models adjust for patient and facility characteristics, and stratified by highest level. Conclusions of this analysis are identical, although point estimates varied slightly (Supplemental Table).

Discussion

In crude analysis, patients in ACS-verified centers had a higher risk for mortality, ICU admission, unplanned return to the OR, and unplanned intubation; however, with the exception of unplanned intubation, these differences were attenuated in the model that was adjusted for facility characteristics, as well as in the model

Table 4
Adjusted[a] risk ratios for patients admitted to ACS-verified vs. non-verified centers, stratified by highest level of designation (state or ACS).

	I		II		III		IV		
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	*P*-value[†]
Mortality	1.00	0.95 to 1.06	1.04	0.98 to 1.10	0.84	0.72 to 0.99	0.25	0.12 to 0.54	<0.001
ICU	1.01	0.97 to 1.04	1.01	0.98 to 1.05	0.99	0.95 to 1.04	1.11	1.02 to 1.21	<0.001
Unplanned return to OR[b]	1.14	0.90 to 1.40	1.06	0.82 to 1.39	0.89	0.53 to 1.50	0.67	0.17 to 2.70	0.062
Unplanned Intubation[b]	1.35	1.11 to 1.65	1.13	0.89 to 1.44	1.65	0.89 to 3.05	0.28	0.10 to 0.81	<0.001
Hospital Disposition									
Acute care	0.76	0.59 to 0.97	0.99	0.79 to 1.23	0.99	0.79 to 1.24	1.04	0.54 to 2.00	<0.001
Home w/ home care services	1.00	0.82 to 1.20	0.76	0.62 to 0.93	0.88	0.69 to 1.12	1.60	0.89 to 2.80	<0.001
Intermediate care facility	0.47	0.30 to 0.74	0.75	0.53 to 1.10	0.79	0.45 to 1.40	1.00	0.21 to 5.10	<0.001
Rehab nursing home	1.03	0.95 to 1.11	1.04	0.99 to 1.08	0.99	0.94 to 1.05	1.20	0.95 to 1.60	<0.001

Abbreviations: ACS, American College of Surgeons; RR, risk ratio; CI, confidence interval; ICU, intensive care unit; OR, operating room.
[a] Adjusted for region of the US, hospital bed size, percent burn admissions at facility, payer mix (percent Medicaid, percent privately insured), gender, race/ethnicity, age, Charlson comorbidity index, injury severity score (ISS), drug or alcohol use, location of injury (home or residential institution, industry, farm, recreation, street, or other/unspecified), whether the injury was work-related, and whether the patient was transferred from another facility.
[b] Analysis of complications excluded centers reporting zero complications.
[†] *P*-values are for interaction term for ACS verification by highest level of designation, in a fully adjusted model.SOURCE: Authors analysis of data from the National Trauma Data Bank, 2010–2015.

adjusted for patient characteristics. Neither of these models provided sufficient evidence for differences between ACS-verified and state-designated centers for mortality, ICU admission, and unplanned return to the OR. Of interest, however, ACS-verified centers had a greater risk of unplanned intubation in both the facility characteristics-adjusted and the patient characteristics-adjusted models.

Stratified analyses revealed that while among Level I and II centers, mortality risk was similar between ACS-verified and state-designated centers, mortality was 16% lower at ACS-verified Level III centers and 75% lower at ACS-verified Level IV centers. This suggests that while state verification processes appear to function well in terms of designating Level I and II centers that achieve similar outcomes to ACS-verified centers, the processes may not function as well for Level III and IV centers. For Level IV centers in particular, it may be important to re-evaluate the state designation process to identify factors associated with this substantial difference in mortality risk.

To our knowledge, this study is the first to compare ACS-verified centers with state-verified centers across multiple trauma levels—previous studies have focused only on Level I or Level I and II. Results from our stratified analysis are consistent with a previous study using NTDB 2002 to 2006 that found no significant difference in overall mortality when comparing ACS-verified and state-designated Level I facilities [11]. However, a later study using the NTDB 2007 to 2008, compared ACS-verified and state-designated Level I and II centers and found that ACS verification was associated with a lower median observed-to-expected (O/E) mortality ratio in level I centers (0.95 [IQR, 0.82 to 1.05] vs. 1.02 [0.87 to 1.15]; $p < 0.01$) and no difference in Level II centers (0.94 [0.81 to 1.06] vs. 0.87 [0.71–1.09], $p = 0.30$) [10]. It should be noted, however, that previous versions of the NTDB included a higher proportion of Level I and II trauma centers, and fewer lower-level and undesignated centers, meaning that the data set may have suffered greater selection bias. While the NTDB 2010–2015 used in this study is also vulnerable to such selection bias, we expect that such bias has been reduced relative to the previous versions of the data set.

Our finding that ACS-verified centers have an increased risk of unplanned intubation was surprising, and lends itself to various interpretations. Although we controlled for injury severity, comorbidities, and demographic factors, residual confounding may have been present by variables such as by pre-stabilization vital signs, which are not reliably recorded in the NTDB. Another explanation may be a greater comfort with intensive interventions at ACS centers, or, alternately, that surgeons at ACS centers have more aggressive extubation protocols, and therefore would need to re-intubate more frequently when patients fail extubation. In contrast, a previous single-center study comparing outcomes pre- and post-ACS verification found that unplanned intubations were reduced after ACS verification, [8] however, these results may be due to temporal factors within the institution, unrelated to the verification.

Our study was limited by its observational nature and the constraints of the NTDB, which is known to have missing physiologic data [19] as well as differential reporting of some characteristics, such as comorbidities [20]. We addressed these constraints by adjusting for both patient and facility characteristics, although, as with all studies of this nature, our results are potentially vulnerable to residual confounding. Although the NTDB is large and reflects facilities across the United States, its voluntary participation from hospitals can impact data quality and selection bias. Results are not population-representative, and may skew towards higher-volume trauma centers. In addition, compliance with NTDB standards has been shown to vary across centers [21], so measurement error due to variations in data quality control may be associated with other institution-level factors, such as lack of resources.

Another important consideration is the impact of geography on patient outcomes. It is possible that the ACS-verified Level IV centers may differ from state-designated centers in terms of their proximity to higher level centers. More isolated lower level centers may be expected to have higher mortality levels due to patients either being more likely to die in transit or choosing not to transfer patients to higher level centers due to concerns about risks associated with a lengthy transfer. The NTDB does not contain geographic data, so we were unable to explore differential geographic factors as an explanation for our results.

Finally, because the state designation process differs between states, our aggregated analysis may have masked important state-level differences between state-designated and ACS-verified centers. State-level data is not available in the NTDB; however, an exploration of these comparisons at the state level may be an important avenue for future research.

Our study was strengthened by using by far the largest dataset in the published literature on this topic, including 4,044,449 cases from 1023 facilities over six years. Furthermore, our analysis included trauma centers from Level I-IV, and examined differences both aggregated and stratified by level.

Our results suggest that while outcomes tend to be aligned between ACS-verified and state-designated Level I and II centers, state-designated Level III and particularly Level IV centers show poorer outcomes relative to their ACS-verified counterparts. Further research is needed regarding which aspects of the ACS verification process are most important and most cost-effective in achieving optimal patient outcomes—this could inform state-level decisions regarding trauma center requirements. While one long-term option may be to remove the state-level verification process and use only ACS verification for trauma center requirements, the state-level process enables each state to make decisions about its trauma system based on its unique population, geography, and resources, which in some cases may offer advantages. Given the large difference in mortality found between ACS- and state-designated Level IV centers specifically, state-level trauma systems should ensure that verification processes for Level IV centers are adequately stringent to ensure a high quality of patient care.

Author Contributions

All authors designed the study, AR conducted statistical analysis, FS, LG, and AR composed the manuscript, and all authors reviewed and edited final manuscript.

Conflicts of interest

The authors have no conflicts of interest, financial or otherwise, to disclose.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2018.09.038.

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