Working Paper

Tracking Spending, Mortality, and Readmissions as the Number of Comprehensive Trauma Centers Increases

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ABSTRACT

Media stories have raised concerns about Florida's expansion of advanced trauma centers, where newly designated centers began charging high trauma activation fees for relatively minor injuries. Texas experienced similar expansion of Level II trauma centers between 2011 and 2019. To study the association between trauma center upgrades and patient outcomes, we examined commercial claims from a large insurer in Texas to track changes in spending, mortality, and readmissions of trauma patients. In a few cases newly upgraded trauma centers had higher spending relative to facilities that were operating in 2011, and many more had lower mean spending. Nevertheless, the handful of newly upgraded trauma centers with higher spending exceeded mean spending at existing centers substantially. We found little difference in readmissions or mortality. Given that new Level II trauma centers in Texas were located in areas lacking adequate access to advanced trauma care, the Texas expansion plausibly improved patient welfare.

Keywords: Trauma centers, spending, mortality, readmissions

INTRODUCTION

Injuries are the fourth leading cause of death for all ages and the leading cause of death for persons between the ages of 1 and 44.[1] They accounted for 35 million of 130 million visits to emergency departments in the U.S. in 2018.[2] Recent estimates are unavailable, but a 2016 study estimated the national medical cost of injuries to be $56 billion annually in 2010.[3]

In 2002, the National Uniform Billing Committee approved a new billing code, commonly referred to as a trauma activation fee, which was meant to compensate trauma centers for keeping multiple specialists and costly equipment on standby to care for patients with complex injuries.[4] A recent study found only 8.8% of 525 trauma centers were willing to report their trauma activation fees, but the amount for those facilities that did report varied from $200 to $23,000.[5]

The American College of Surgeons (ACS) issues guidelines to state and regional authorities for designating hospitals as trauma centers based on population needs and the staffing and equipment they provide to treat injured patients.[6] The ACS then verifies the level of services available, with Level I (academic) and Level II (non-academic) centers providing definitive care for the most severely injured patients, including those with high complexity or multiple trauma injuries. A Level V center performs initial evaluation, stabilization and diagnostic capabilities; while Level III and IV centers provide more advanced care, but may transfer the most severely injured patients to Level I and II centers.[7]

In 2014, the Tampa Bay Times reported that the for-profit hospital system HCA opened a network of trauma centers in Florida in 2010 and began charging especially high trauma activation fees for people with minor injuries. One teenager who suffered a concussion with no broken bones or blood loss was charged a trauma activation fee of $33,000.[8] The Tampa Bay Times analyzed more than 10 million patient billing records and found that the average fee in Florida grew from $2,555 in 2006 to $10,825 in 2013.[9] More recent news stories report that the number of Level I and II trauma centers nationwide grew from 305 in 2008 to 567 in 2020, and suggests that the trauma activation fees they are charging are responsible for the large rise in trauma spending.[10]

Some research suggests that the expansion of trauma centers in Florida may have been justified. The increase in fees reported for Florida was not adjusted for differences in injury severity or other patient characteristics that may have changed over time. Other studies suggest that case severity and the number of procedures for patients presenting to emergency departments has risen over time.[11] In general, access to trauma care in Florida is relatively low when the ratio of capacity to demand is considered, especially for cities in the lower half of the state.[12] Moreover, commercial hospital prices were generally rising at double digit levels throughout the U.S. during this time period.[13] Therefore, the anecdotal reports of extraordinary bills in Florida may partly have been a reflection of rapid hospital price increases that were occurring throughout the country.

Texas experienced a similar expansion of Level II trauma centers that began in 2011. The state suffered a severe shortage of high-level trauma care during Hurricane Ike, which prompted the State Legislature to request a formal evaluation from the ACS. In 2010, the ACS concluded that the trauma capacity of Houston hospitals was insufficient to meet daily and surge demands.[14] These concerns were echoed in a 2015 Houston Chronicle story, which noted that the city had one Level I trauma center per 3 million people, while the ACS recommended one Level I center per 1 million population.[15]

In this study, we examine commercial insurance claims from a large insurer in Texas to track changes in spending, mortality, and readmissions of trauma patients associated with trauma center expansion. We examine changes over time in these outcomes for trauma patients who visited hospitals with a pre-existing trauma designation, compared to trauma patients treated at hospitals that were upgraded to Level I or II status between 2011 and 2019. We have information on patient demographic characteristics, injury type, injury severity, and patient comorbidities. Therefore, we are able to control for changes in patient characteristics that are likely to occur as new Level I or II centers treat more severe patients. We are able to distinguish spending increases that occurred over time for all hospitals, versus those associated with upgraded trauma centers.

Results from this study will inform policy makers and commercial insurers who are concerned about unfair billing practices as more hospitals open Level I or II trauma centers. Cities experiencing geographic expansion will require more trauma centers as new suburbs far from existing trauma centers continue to increase their population counts. We seek to measure whether upgrading represents a new opportunity to raise prices, or whether prices are generally rising for all trauma care. We also track changes in readmission rates and mortality for upgraded trauma centers, to determine whether newly designated trauma centers match existing centers in terms of quality.

THEORETICAL FRAMEWORK

The decision of a hospital to upgrade its trauma facilities is likely a product of a complex process involving important demographic, socioeconomic and legal/policy factors, as well as competition among hospitals and the market power of payers. Demand for advanced care, in terms of patient volume and geographic proximity, matters greatly for the hospital's upgrade decision. Hospitals must also consider the capital and labor costs of upgrading and delivering more advanced care, which both affect profits.

The economic feasibility of upgrading also depends on the number of competing facilities with whom patients may also receive care. Such competition can lead to lower costs and higher quality, as both newly upgraded and existing facilities may need to improve to bring in sufficient patient volumes in a competitive landscape with more Level I and II trauma centers. Additionally, upgraded facilities may be able to recapture some of the revenues that were previously lost in transferring patients to higher capability centers. But by entering the market for severe trauma care, hospitals still need to continue to compete in non-Level II care. Treating more severely injured patients may leave fewer bed, staff, or other resources for the treatment of less urgent patients. All hospitals must account for possible capacity constraints – both in terms of physical capital such as beds, but also in adequately trained providers.

The competitive landscape among trauma centers interacts with that of insurance companies as well, including the payer mix of the local patient population. By entering the market for higher severity trauma care, a hospital may increase its bargaining power with insurance companies, potentially resulting in higher payments, including the trauma activation fee available only to Level I or II facilities. The increase in the number of competing trauma centers, however, may also provide the insurance company with greater negotiating power.

It is therefore theoretically ambiguous how the increase in the number of Level II trauma centers would impact measurable patient outcomes related to quality and spending per trauma case. Spending per patient may increase as a result of newly acquired market power or increased bargaining leverage in discussions with insurers, as well as with access to new billing codes. Spending per patient may instead decrease if the competitive effects of more high capability trauma centers overwhelm the other forces. Similarly, quality may increase as trauma centers compete more aggressively with one another, or it may decrease as patient volumes are diverted to more facilities and training is impacted. This study aims to assess the association between facility upgrades in a few large geographic markets and these outcomes of interest.

Selection effects likely determine which and how many hospitals choose to upgrade to become Level II trauma centers. We do not observe individual hospitals' costs of providing trauma care, so we cannot directly estimate an economic model of entry into the Level II market as a function of costs and prices. Nevertheless, our reduced form estimation yields valuable insights on spending and patient outcomes, which are useful to policy makers in Texas and in other parts of the country where population shifts may call for more advanced trauma centers.

NEW CONTRIBUTION

Our study evaluates critical aspects of the current discourse surrounding the impact of the spread of upgrading trauma centers. The main contribution of our study is the rigorous empirical analysis of patient outcomes using administrative claims data, while controlling for important features of patient severity and caseload, as well as systemic features of the healthcare markets in question. Specifically, although past research has documented some patterns of spending and outcomes at trauma centers, evaluation of the impact of recent expansions of upgraded facilities has been limited to anecdotal evidence or simple summary statistics of charges. Such an approach does not account for likely relevant details, such as injury severity and the broader increase in healthcare costs.

It is not immediately obvious what impact large increases in supply of high capability trauma centers should have on our outcomes of interest, especially given the initial sparsity of such facilities in Texas's major metropolitan areas. Health outcomes, such as readmissions and mortality, could improve with the growth of Level II centers in underserved regions as increased capacity and closer proximity of trauma centers might allow for specialized treatment of severely injured patients that may not be able to access the capabilities of a Level II trauma center without the expansion. It is also possible, however, that upgrading facilities do not provide the same level of specialized care as existing facilities or impact quality of care at existing facilities by diverting patient volume crucial for such specialized care provision. Upon upgrading, new Level II centers can begin charging trauma activation fees, potentially increasing costs.

Increased costs may reflect, however, the increased severity of injury a hospital encounters once equipped to handle more complex trauma cases. To understand these, and other, countervailing forces and assess the overall impact of trauma center expansion in Texas, a detailed empirical analysis is necessary.

METHODS

Data

We conducted a secondary analysis of Blue Cross and Blue Shield of Texas (BCBSTX) insurance claims from 2011 to 2019. Patients were limited to the three largest Metropolitan Statistical Areas in Texas (MSA; Austin-Round Rock, Dallas-Fort Worth-Arlington, Houston-The Woodlands-Sugar Land) where we identified facilities verified as Level II trauma centers during our time period.

Patients aged 16 to 64 from these MSAs were selected if their claim had one or more of the following: (1) a trauma activation revenue code (068X), (2) a trauma related DRG code,[16] or (3) an urgent/emergent admission in conjunction with an injury related ICD diagnosis code. See Appendix Table 1 for a list of codes used. Following previous literature, we excluded patients with isolated diagnoses involving insertion of foreign objects into body orifices or late effects of trauma. We also excluded patients with isolated sprains if they did not have a trauma activation and did not die.[17] The list of corresponding ICD10 trauma-related diagnosis codes was derived from the ICD 9 codes listed in the previous literature using the National Center for Health Statistics' (NCHS/CDC) General Equivalence Mappings (GEMs) as a crosswalk between the two versions of diagnosis codes.[18]

Both facility claims and professional claims were extracted for each trauma visit. Each claim contains an "allowed amount," which is the contracted amount that should be paid to the provider for the relevant service by both the insurer and the patient combined. For confidentiality reasons, our dataset included the total sum of the allowed amounts for all claims associated with a trauma visit, as opposed to the allowed amount in each individual claim. Therefore, although we can determine whether a trauma activation fee was charged to a patient, we do not know the exact amount of that fee. Thus, we are examining changes in spending that occur after a hospital upgrades to become a Level I or II trauma center, accounting for changes in patient case mix severity that are expected to increase after a facility upgrade.

The patient outcomes of interest were an indicator of all cause readmission to any hospital within 30 days of discharge, as well as mortality within 24 hours of the initial trauma treatment, as defined by BCBSTX using each patient's full set of claims.

We controlled for patient demographics using age and sex. To account for pre-existing conditions and injury severity, the Charlson Comorbidity Index, New Injury Severity Score, and length of stay were calculated for each patient.[19] The Charlson Comorbidity Index equals the weighted sum of the probability of inpatient death associated with chronic illnesses such as diabetes, hypertension, and chronic obstructive pulmonary disease as derived from a previous study analyzing inpatient claims data. Illness conditions underlying the index were included as categorical indicator variables in the regressions to account for the possibility that underlying patient frailty can influence patient outcomes. The NISS score was developed by trauma researchers to characterize the severity of the multiple injuries that are commonly suffered by patients involved in motor vehicle accidents, gunshot wounds, and other trauma incidents.

Dummy variables were included to identify body regions of injury for up to three of the most severe injuries identified. Patients also had indicators for inpatient vs outpatient claims and for transferring into or out of trauma facilities in order to control for any systematic differences in the injury severity or need for a higher level of care.[20] In cases where there was a trauma claim for both an initial and second stay at a separate facility for a transfer patient, we attempted to select the stay providing the bulk of the immediate trauma-related care to prevent multiple observations for a single traumatic event. If the initial stay was one day or less, then the initial stay was deleted and the second stay was marked as a transfer "in" under the presumption that these patients were likely transferred due to the inability of the first hospital to meet all of the trauma treatment needs. If the initial stay was more than one day, then we omitted the second stay and marked the initial stay as a transfer "out." We assumed that these patients are more likely to be transferred for insurance purposes or to be closer to home rather than for immediate trauma-related care.

Regional characteristics include a county-level wage index and Metropolitan Statistical Area (MSA) indicators.[21]

Identifying Upgrades to Level II

During the sample period, the number of new advanced trauma centers increased in Texas in two different ways: 1) creation of a new trauma center at a hospital that did not have one before, or 2) upgrading of an existing Level III or IV trauma center to Level I or II. The year and month of verification as a Level I or II trauma center was determined using the lists of current trauma facilities and verification status files from the Texas Department of State Health Services (TXDSHS).[22] Historical versions of these files were obtained using the website Wayback Machine.[23] Two hospitals in our sample entered as a new Level II trauma center while the remaining upgraded from Level III or IV. To protect the identity of the facilities and their data, all new Level II facilities in our data are treated similarly in our analyses.

The Appendix Figure 1 contains maps of the Austin, Dallas-Fort Worth, and Houston metro areas, with locations of Level I or II trauma centers in 2011 and 2019. These maps illustrate that these newly opened centers were located well away from existing facilities, so that they improved timely access to advanced trauma care as more people moved to outlying metropolitan locations.

Statistical Analyses

Descriptive statistics were used to compare the number of trauma patients at new and existing trauma centers at the beginning of the sample (in 2011) and the end (2019) by NISS severity score. We also examined the mean spending and the readmission and mortality rates for these subgroups. In addition, we compared the patient characteristics and types of injuries treated.

We then applied regression analysis to test whether the new trauma centers were associated with higher spending, 30-day readmissions, or 24-hour mortality using two different regression specifications. We estimated one specification that examined changes in outcomes relative to existing Level I and II trauma centers for each of the individual facilities that upgraded during the sample period. We then estimated another specification that tested for any overall difference in outcomes for facilities that upgraded between 2011 and 2019 versus existing facilities.

The first specification includes an indicator for when a patient is treated at a new Level I or II center during the hospital's pre-upgrade period and a second that indicates if a patient is treated at a new Level I or II trauma center after upgrade. The coefficients are interpreted relative to the existing Level I or II trauma centers. Interactions between each year and upgraded variable are also included to capture any differential impacts of treatment at newly upgraded facilities over time. The analysis included controls for regional effects, patient characteristics, and injury severity.

$$(1)\ Y_{iht} = \alpha_0 + \beta_t + \delta PreUG_{iht} + \rho UG_{iht} + \gamma_t UG_{iht} * Year_{iht} + \theta Z_{iht} + \varepsilon_{iht}$$

Where Y_{iht} represents the three outcomes of interest noted above resulting from patient i's trauma care visit to hospital h. β_t represents years fixed effects for the year in which the visit occurred. $Year_{iht}$ is a vector of year indicators set to 1 for the year in which the visit occurred. The variable $PreUG_{iht}$ is an indicator equal to 1 if the patient was admitted to the facility before the month/year it upgraded to become a Level II trauma facility or in previous years. The variable UG_{iht} is an indicator equal to 1 if the patient was treated at the facility during or after the month/year it upgraded to become a Level II trauma facility during the study period. The coefficients γ_t capture the interaction of the year of the hospital visit and whether the facility had upgraded. The vector Z_{iht} represents other patient and market characteristics likely to influence the cost of the visit, and ε_{iht} is an error term.

To determine if the overall differences in outcomes between visits to upgraded facilities were statistically different from those at existing facilities, we calculated the marginal effect of upgrading by year, denoted by Δ_t in equation 2. We performed a t-test of significance, and the coefficients and CIs of these effects were graphed by year.

$$(2)\ \Delta_t = \rho + \gamma_t$$

The second specification includes individual hospital fixed effects, as well as interactions of those fixed effects with verification status. Similar to the first specification, the regression also includes year dummies and controls for regional, patient, and injury differences.

$$(3)\ Y_{iht} = \alpha_0 + \beta_t + \delta_h + \gamma_h UG_{iht} + \theta Z_{iht} + \varepsilon_{iht}$$

Where δ_h represent hospital fixed effects for upgraded facilities and $\gamma_h$captures the post-upgrade hospital fixed effect for upgraded facilities.

To determine if the differences in outcomes between visits to individual upgraded facilities were statistically different from those at existing facilities, we calculated the marginal effect of treatment at each upgraded hospital, denoted by Ω_h in equation 4.

$$(4)\ \Omega_h = \delta_h + \gamma_h$$

Recall that we do not observe the dollar amount of trauma activation fees associated with any particular visit. Therefore, even if we observed a change in outcomes associated with upgrading for a particular hospital (the coefficient γ_h in equation 4), we would have no way of gauging whether that change was due to excessive activation fees. By focusing on Ω_h, we can assess changes associated with upgrading relative to performance at existing trauma centers. We performed a t-test of significance, and the coefficients and CIs of these effects were graphed by hospital.

We chose these two specifications rather than estimating a simple two-way fixed effect regression to allow for potential hospital and temporal heterogeneity in the effects of upgrading on our outcomes of interest, as well as to avoid known issues of such aggregation in a setting with staggered upgrades.

All regressions involving spending were estimated using a generalized linear model (GLM) with a log link and gamma distribution to avoid biases that may result from estimates derived from ordinary least squares with the log of spending as the dependent variable.[24] All regressions involving readmissions and mortality were estimated using a linear regression model to allow for comparability across outcomes. The results do not differ markedly if we use a non-linear model. With few exceptions all regressions included all of the controls listed above. Spending regressions included the wage index which was excluded from readmission and mortality regressions. Given that mortality was measured within the 24-hour time period, the mortality regressions also excluded the indicators for outpatient claim type and length of stay.

Each analysis was first performed for low severity patients (NISS<9) and then performed again for high severity patients (NISS 9+).[25] The trauma literature categorizes patients with NISS values <9 as having minor or moderate injuries. Within the regressions by patient severity, we included dummy variables that further divided NISS severity into serious (9 to 15), severe (16 to 24), and critical (25+), because preliminary analyses suggested that this variable was an influential determinant of outcomes.

Sensitivity Analysis

While hospitals may begin to act as a Level II trauma center at pursuit of verification, they are unable to use trauma revenue codes in billing for care until verification. Given this billing limitation and our ability to more accurately identify verification dates, we use verification dates for our main analyses, but we perform a sensitivity analysis using pursuit dates. We identified the year each new Level II trauma center began pursuit of verification using a mixture of TXDSHS documents and internet searches of hospital and news websites.[26] If we were unable to identify the exact timing of pursuit, we estimated the pursuit as 18 months prior to the verification date, since most trauma centers have 18 to 24 months of active pursuit before verification. All regressions were performed again using pursuit date rather than verification date.

The NISS and Injury Severity Score (ISS) are both widely used in trauma literature. In a patient with more than 1 injury, the ISS will only include a single entry per body region. Thus, the ISS may overlook a second injury within a region to include a more minor injury from a separate body region.[27] While the ISS is limited by this fact, many researchers continue to use the ISS instead of NISS.[28] Therefore, we re-estimated all of our regressions using ISS in place of the NISS.

Additionally, we performed all regressions omitting transfer patients from our sample to eliminate any bias in our selection of transfers. This approach also addresses the inability to properly assign mortality if a patient was treated at multiple hospitals and ensures that each observation represents the full trauma treatment for each patient.[29] Transfer patients, particularly those that transfer out, have been omitted in much of the previous literature comparing trauma centers.[30]

Finally, many of the higher severity patients stay multiple days in the hospital. Therefore, extraordinary trauma fees on the first day could be masked by payments associated with the extended length of stay in the hospital. Therefore, we re-estimated all regressions limiting our sample to patients with a length of stay of 1 night or less.

Table 1: Outcomes and Patient Characteristics at Existing Versus New Trauma Centers by Year and Severity

		Existing Level I & II Trauma Centers				New Level II Trauma Centers			
		2011		2019		2011		2019	
		NISS < 9	NISS 9+	NISS < 9	NISS 9+	NISS < 9	NISS 9+	NISS < 9	NISS 9+
Cases		1166	879	1186	968	339	133	639	597
Mean Spending		$15,766	$68,327	$16,410	$60,256	$14,758	$57,447	$21,662	$58,568
30 day readmission		1.7%	6.0%	1.6%	6.5%	3.5%	8.3%	2.8%	6.2%
24 hour mortality		0.1%	1.6%	0.3%	0.8%	0.0%	0.8%	0.5%	0.7%
NISS:	0 to 1	25.2%		31.2%		16.8%		24.1%	
	2 to 3	29.7%		25.6%		33.3%		26.3%	
	4	19.1%		18.0%		22.1%		20.5%	
	5 to 8	26.0%		25.2%		27.7%		29.1%	
	9 to 11		27.9%		23.8%		34.6%		26.6%
	12 to 15		24.7%		30.1%		27.8%		34.5%
	16 to 24		28.4%		28.9%		28.6%		25.5%
	25+		19.0%		17.3%		9.0%		13.4%
Injury body region:	Head/neck	35.7%	46.5%	24.3%	42.3%	35.1%	41.4%	18.8%	38.9%
	Chest	9.1%	39.5%	8.9%	31.8%	11.2%	33.1%	9.9%	30.8%
	Abdominal & pelvic content	9.4%	16.0%	9.8%	15.6%	11.8%	17.3%	9.4%	16.8%
	Extremities & pelvic girdle	29.9%	42.1%	31.1%	44.2%	34.8%	51.9%	29.3%	49.2%
	Face	7.0%	12.7%	7.8%	7.1%	4.1%	8.3%	9.4%	5.5%
	External	51.8%	20.5%	47.6%	15.7%	52.5%	23.3%	52.0%	11.6%
Male		55.8%	70.9%	54.0%	67.1%	50.1%	57.9%	60.6%	66.5%
Mean Charlson Index		0.7	1.0	0.8	1.0	0.7	1.0	0.8	0.9
Mean Age		37.0	38.5	39.6	40.9	39.8	42.5	40.4	42.3
Mean Length of Stay		1.4	7.1	1.3	6.3	1.7	4.9	1.8	6.1
Outpatients		63.7%	8.4%	61.1%	8.9%	50.1%	6.0%	50.4%	7.4%
Transfer In		0.7%	2.6%	0.8%	3.3%	0.6%	0.8%	0.9%	2.7%
Transfer Out		0.0%	0.5%	0.1%	0.6%	0.6%	2.3%	0.2%	0.5%
MSA:	Austin	26.3%	18.0%	20.0%	17.4%	3.0%	3.0%	15.7%	12.6%
	Dallas/Fort Worth	59.4%	55.9%	64.0%	48.8%	87.6%	88.7%	68.4%	69.5%
	Houston	14.3%	26.2%	16.0%	33.9%	9.4%	8.3%	16.0%	17.9%

Notes: NISS= New Injury Severity Score; MSA= Metropolitan Statistical

RESULTS

Table 1 presents descriptive statistics for trauma visits to facilities that were Level I or II trauma centers ("existing") in 2011 compared to hospitals that upgraded to Level I or II between 2011 and 2019. The proportion of severely injured patients (NISS 9+) treated at existing trauma centers remained relatively stable between 2011 and 2019 (43% and 45% respectively). In contrast, severely injured patients accounted for only 28% of patients in 2011 for upgrading facilities, and 48% in 2019 after all nine hospitals upgraded. We do not report calculations combining severely and less severely injured patients in Table 1, but the mean values of the NISS and Charlson Comorbidity Index in 2011 were 8.9 and 0.8 respectively, and 9.5 and 0.9 in 2019.

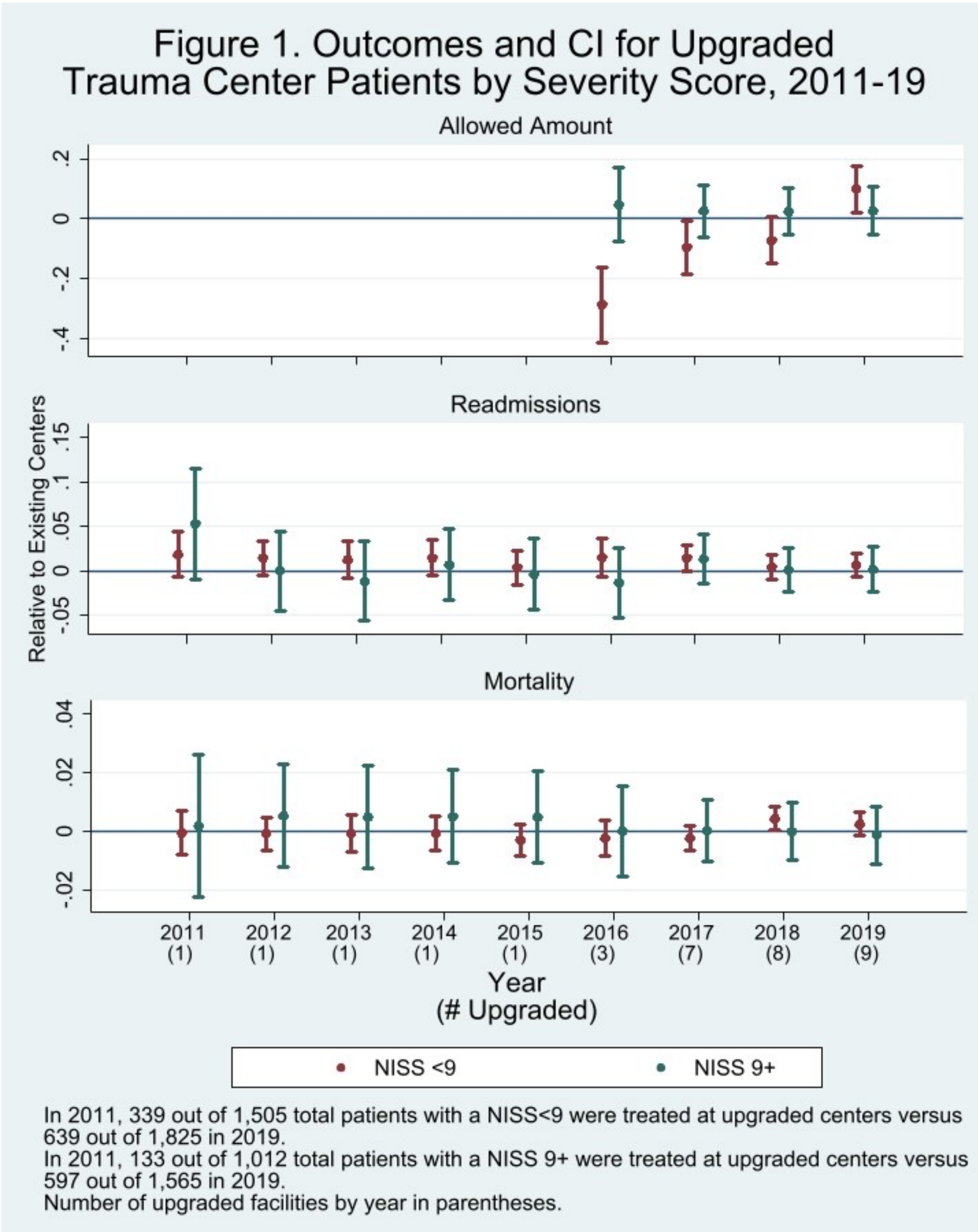
In all years and for both existing and upgraded trauma centers, patients with injury severity scores that were 9 or higher cost at least twice as much to treat as patients with less severe injuries. However, there is no dramatic increase in spending on severely injured patients for facilities that upgraded to Level II between 2011 and 2019. Spending on severely injured patients was lower among upgraded than existing facilities in 2019 ($58,568 vs. $60,256), although upgraded facilities had higher spending than existing facilities on less severely injured patients at the end of the sample period ($21,662 vs. $16,410).

Readmission after 30 days was also at least twice as high for both years and facility types among more severely patients. Mortality rates were higher for severely injured patients relative to less severely injured patients, with the highest mortality rate among the most severely injured patients at existing trauma centers in 2011.

External injuries to areas such as skin/soft tissues are most common among low severity patient, while injuries to the head/neck and the "extremities and pelvic girdle" (Orthopedists generally treat this latter category) are more common than the remaining injury regions among patients of all types. The percent of patients with injuries by body region sum to well over 100, indicating that trauma patients often suffer injuries to multiple body areas. There is a marked increase in injuries to the chest in all facility types between 2011 and 2019. This increase resulted from a shift in practice patterns to performing a routine CT scan of the chest and abdomen, as opposed to performing a chest X-ray and CT of the abdomen. The higher imaging resolution from CT scans relative to X-ray has been shown to detect more injuries, although this practice is not associated with lower mortality.[31]

Figure 1 presents estimates of aggregated changes in outcomes across all upgraded trauma centers by year between 2011 and 2019. These estimates, denoted by Δ_t in equation 2, represent a linear combination of the coefficient on an indicator for whether the patient was treated in a newly upgraded trauma center (versus an existing trauma center), plus the coefficient of an interaction of this indicator variable with a year fixed effect. Only one hospital had upgraded to Level I or II through 2015. For confidentiality reasons, we cannot report spending differences for an individual hospital, so we report spending changes for 2016 onwards, when a minimum of 3 hospitals had upgraded. And in this set of regressions 2019 is the omitted reference year rather than 2011.

Figure 1: Outcomes and CI for Upgraded Trauma Center Patients by Severity Score, 2011-19.



The spending for low severity patients at newly upgraded centers appears to rise over time, but only in 2019 is the value significantly higher than existing centers. There were no lasting differences in readmission or mortality rates relative to existing trauma centers in Texas. Full regression estimates are available in the Appendix, Table 2.

Figure 2: Outcomes and CI for Upgraded Trauma Center Patients by Hospital and Severity Score

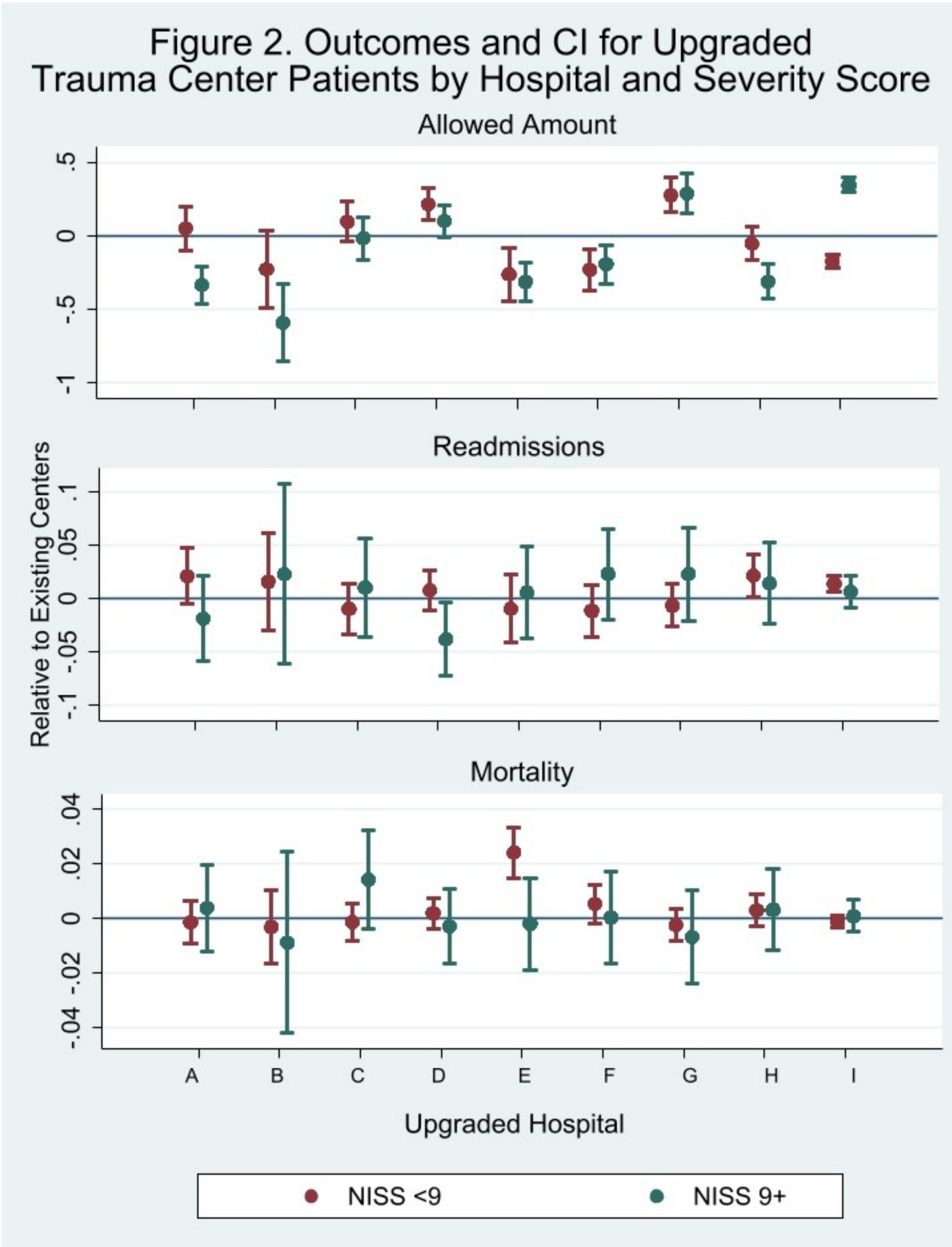


Figure 2 presents estimates of the change in spending, readmissions, and mortality for each of the hospitals that upgraded to a Level I or II trauma center between 2011 and 2019. These estimates, denoted by Ω_h in equation 4, were derived from a linear combination of a hospital fixed effect for each facility (relative to all hospitals with existing trauma centers in 2011), combined with an interaction of the hospital fixed effect with a dummy variable equal to 1 if the patient was treated in a year when the facility had upgraded. Separate regressions were estimated for severely injured patients (NISS 9+) and less severely injured patients (NISS<9). Coefficients estimates from the entire regression are presented in the Appendix, Table 3.

We are primarily interested in the estimates of Ω_h, although the estimates of the interaction between each hospital fixed effect and years when the facility had upgraded help confirm whether each facility raised its allowed amount per patient after upgrading, as one might suspect. The results in Table 3 of the Appendix indicate that 6 out of 9 hospitals raised their spending on less severely injured patients, and 3 out of 9 hospitals raised their spending on more severely injured patients. No facility lowered its allowed amount per patient by a statistically significant amount relative to its own pre-upgrade spending.

Focusing now on the results in Figure 2, between 2011 and 2019, 2 out of 9 hospitals that opened new Level II facilities experienced greater spending on severely injured patients after upgrading relative to existing trauma centers, and 1 of these hospitals along with another hospital also had greater spending on less severely injured patients. These spending differentials relative to existing trauma centers ranged from 21.4% to 34.7%. In contrast, upgrading was associated with significantly lower spending on more severely injured patients in 5 out of 9 upgraded hospitals and 3 out of 9 hospitals for less severely injured patients.

We found many fewer differences in readmissions or mortality for upgraded trauma centers relative to existing facilities. One newly upgraded trauma center experienced a 3.8 percentage point (p=0.03) lower readmission rate for severely injured patients. Two upgraded hospitals had readmission rates that were 1.3 (p<0.001) and 2.1 (p=0.04) percentage points higher for patients with less severe injuries than existing trauma centers. Only a single trauma center experienced a higher mortality rate of 2.4 (p<0.001) percentage points for less severely injured patients after upgrading relative to existing centers. The mortality rate for less severely injured patients in the sample who were treated at existing trauma centers is 0.1%. Therefore, an estimated 2.4 percentage point increase relative to this number would amount to a mortality rate of 2.5%.

The results above suggest that unjustified use of trauma activation fees was not a common phenomenon among facilities that upgraded to Level I or II trauma centers. Moreover, we did not find widespread increases in readmissions or mortality associated with upgrading of trauma centers. Relative to existing Level I and II centers, one newly Level II hospital had a higher readmission rate that was associated with noticeably lower spending (-17.3%, p<0.001), while another newly Level II hospital experienced higher mortality accompanied by lower spending (-26.1%, p=0.005). Both of these changes occurred for less severely patients, suggesting that treating more severely injured patients after upgrading may have negatively affected these facilities' ability to handle less severely injured cases.

Whether trauma centers experienced higher or lower spending per visit after upgrading relative to existing centers, the changes in spending were relatively large. The coefficient estimates for precisely estimated differences were all double digits in magnitude. Many of the newly upgraded hospitals increased their spending substantially post-upgrade suggesting a noticeable increase in prices for trauma care that may have resulted from rising market power of hospitals during the sample period, yet most of the newly upgraded hospitals remained at a level of spending that was equal or lower than spending at existing centers.

Results from each of the sensitivity analyses remained similar to our primary findings. For example, using ISS rather than NISS resulted in a single additional hospital with significantly lower spending for low severity patients in upgraded centers and fewer hospitals with significant differences in readmission rates (Appendix Tables 4 and 5). Removing transfer patients from the sample resulted in one additional hospital with significantly higher spending for high severity patients in upgraded centers (Appendix Tables 6 and 7).

Using pursuit dates rather than dates for verification as a Level I or II trauma center shifted which hospitals have significant values for readmission and mortality, but it does not alter the overall findings for these outcomes. Using pursuit dates to estimate effects on spending resulted in lower overall spending by year at upgraded centers for high severity patients relative to existing centers, but this is likely due to the fact that upgraded centers are not allowed to charge Level I or II trauma activation fees until after verification. Appendix Table 8 contains the results of the year-based pursuit sensitivity analysis. A single hospital that is verified during our sample period began pursuit prior to 2011, meaning that it is classified as an existing trauma center in the pursuit regressions. Due to this change in status, the results of these regressions may not be shared, because it would make it possible to identify the hospital's identity in our primary regressions.

Overall results from limiting length of stay to one night or less were similar to our results for low severity patients, because 82% of the patients with a length of stay of one night or less also had a NISS<9 (Appendix Tables 9 and 10). Which specific hospitals had significant values varied slightly for this sample, but there were still some hospitals with positive and others with negative values for spending, suggesting that not all hospitals behaved similarly. In comparison to our primary findings for low severity patients, there were two additional hospitals with significantly higher readmissions relative to existing centers after upgrading, and there remained no significant overall effect on mortality, even though there was still a single upgraded hospital with higher mortality for low severity patients.

DISCUSSION

Our analysis suggests that many newly upgraded trauma centers in Texas raised the prices they charged to high severity patients after receiving verification to provide advanced care. But only in a few cases did this increase result in spending that was higher in newly upgraded facilities than existing ones. The marginal spending for low severity patients in upgraded centers relative to existing centers was increasing from 2016-2019, resulting in significantly higher spending in newly upgraded centers by 2019.

These overall results of higher spending are aligned with what has been reported in the press, but do not reflect the complete story as told by the data. Not all upgraded trauma centers behaved in the same manner. Even with significant increases in spending after upgrading, many upgraded centers actually had significantly lower spending than existing centers. Yet the magnitude of the increases in spending overall-- and more specifically among the handful of newly upgraded trauma centers that have spending higher than existing centers-- are too large to be ignored. The appropriate response would likely be careful oversight by insurers, rather than a government policy intervention.

Extremely large trauma activation fees are often cited in the press as drivers of higher spending at newly upgraded trauma centers. Unfortunately, the limitations of our data do not allow us to disentangle activation fees from total spending, so we are unable to confirm or deny this assertion. But the anecdotal evidence of high trauma activation fees along with generally higher prices at upgraded centers suggests that agreeing upon appropriate trauma activation fees should be a priority for insurers.

New trauma centers are not without benefit. Most patients are injured and treated for those injuries close to their homes. Even higher severity patients, such as those in motor vehicle accidents and gunshot wounds, are most often treated within 10 miles of their home, although they are more likely to travel further for care than patients with less severe injuries.[32] Using summary statistics for all trauma patients covered by BCBS in Texas, we confirmed that patients were more likely to be treated at a Level I or II trauma center if one exists within their hospital service area (HSA; Appendix Table 11). Given that only a handful of upgraded trauma centers displayed higher readmissions or mortality after upgrading relative to existing facilities, and the increase in timely access to trauma care, the overall expansion of Level I and II trauma centers in Texas may be well justified.

More broadly, our results highlight the value of researchers applying their skills to examine problems identified by investigative reporters. With their close contacts with the community, reporters are often the first to learn of patients who suffer from outrageous hospital bills or receive substandard care. Reporters can often identify particular private companies or changes in government policy that precipitated these unfortunate events. Researchers can complement these investigations by analyzing comprehensive patient databases and applying their empirical skills to control for potential confounders to determine if problems are localized or more widespread. This collaborative effort can provide valuable guidance to leaders in the healthcare sector and policy makers on achieving effective and efficient healthcare.

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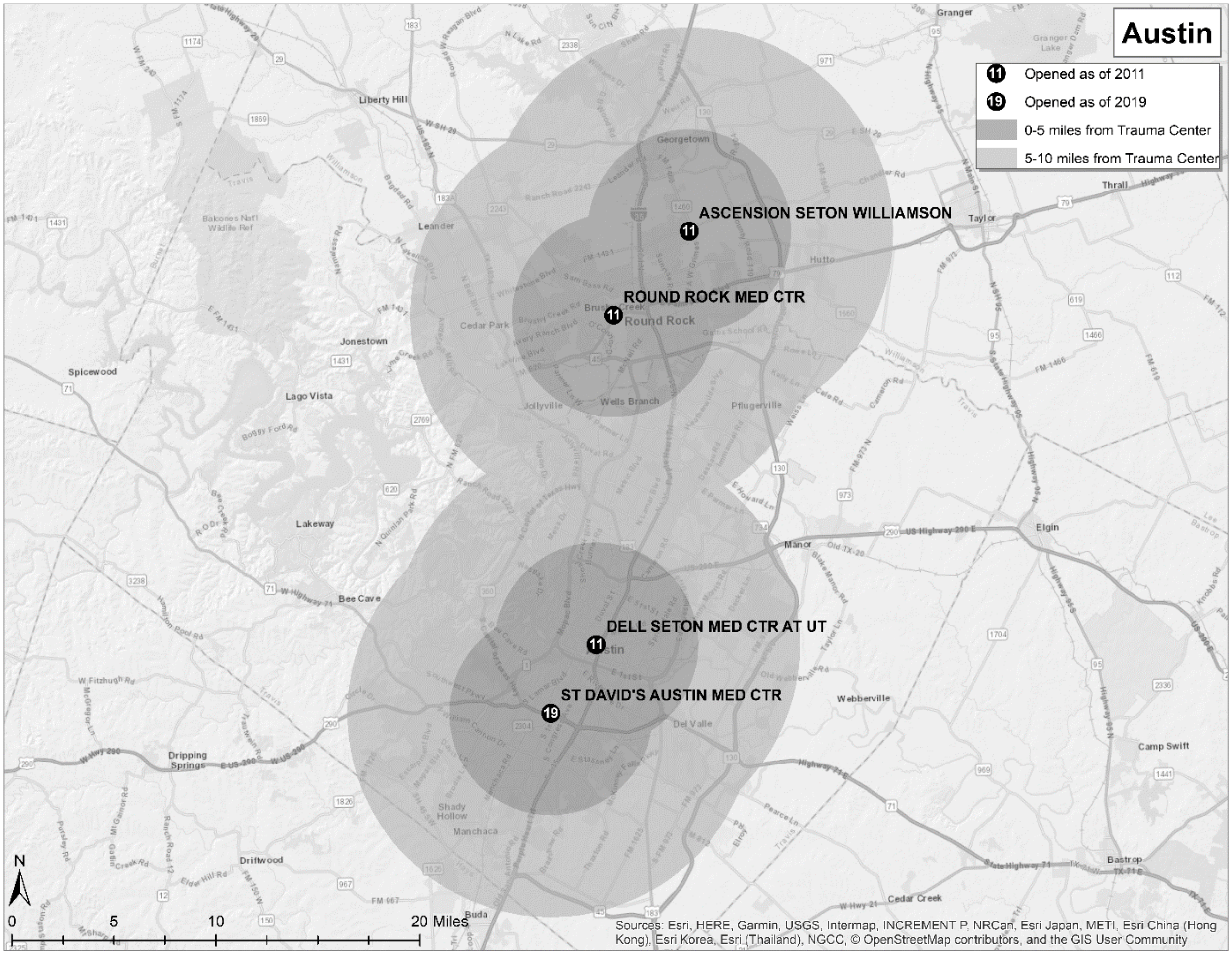
Appendix: Tracking Spending, Mortality, and Readmissions as the Number of Comprehensive Trauma Centers Increases

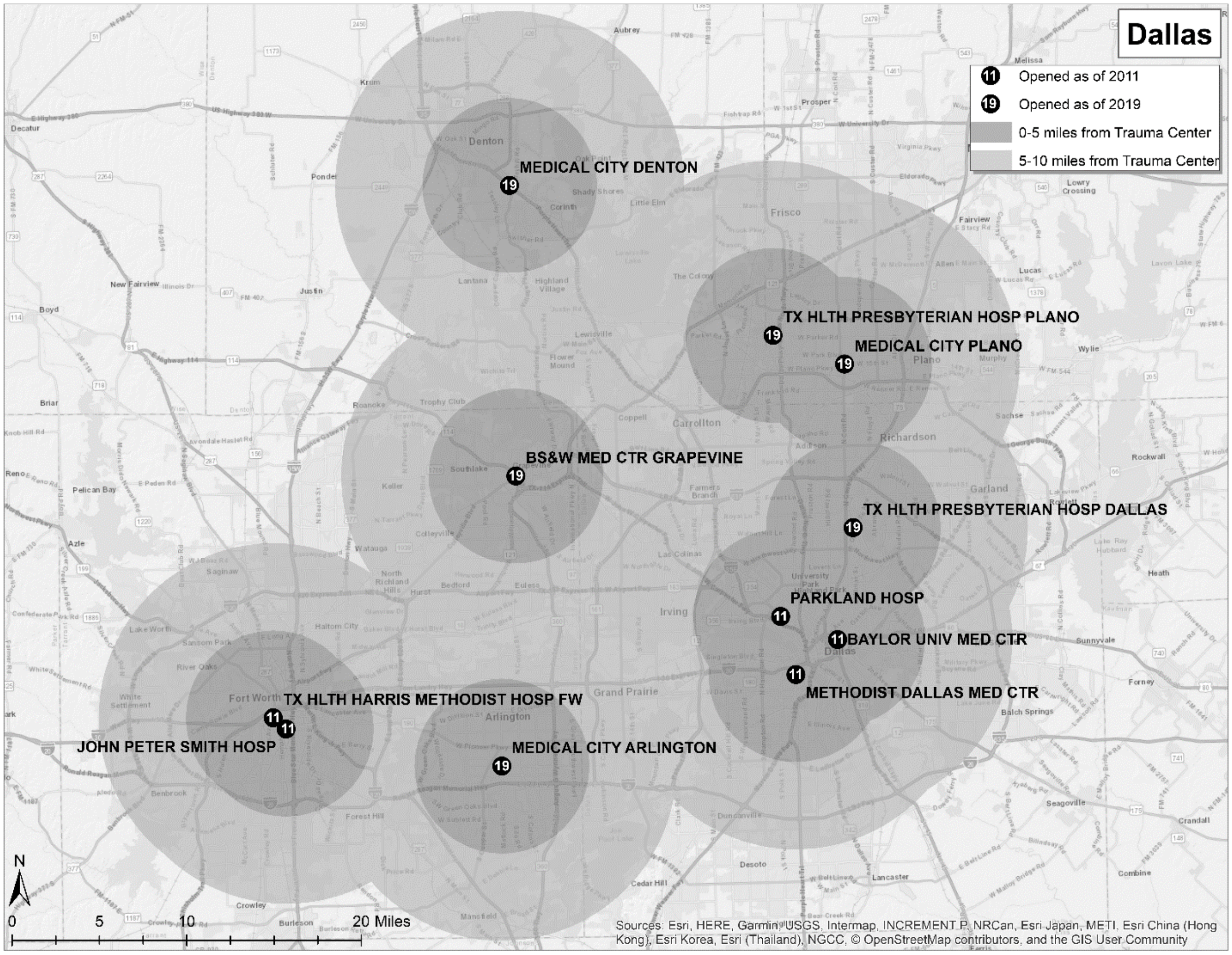
Appendix Table 1: Selection Criteria

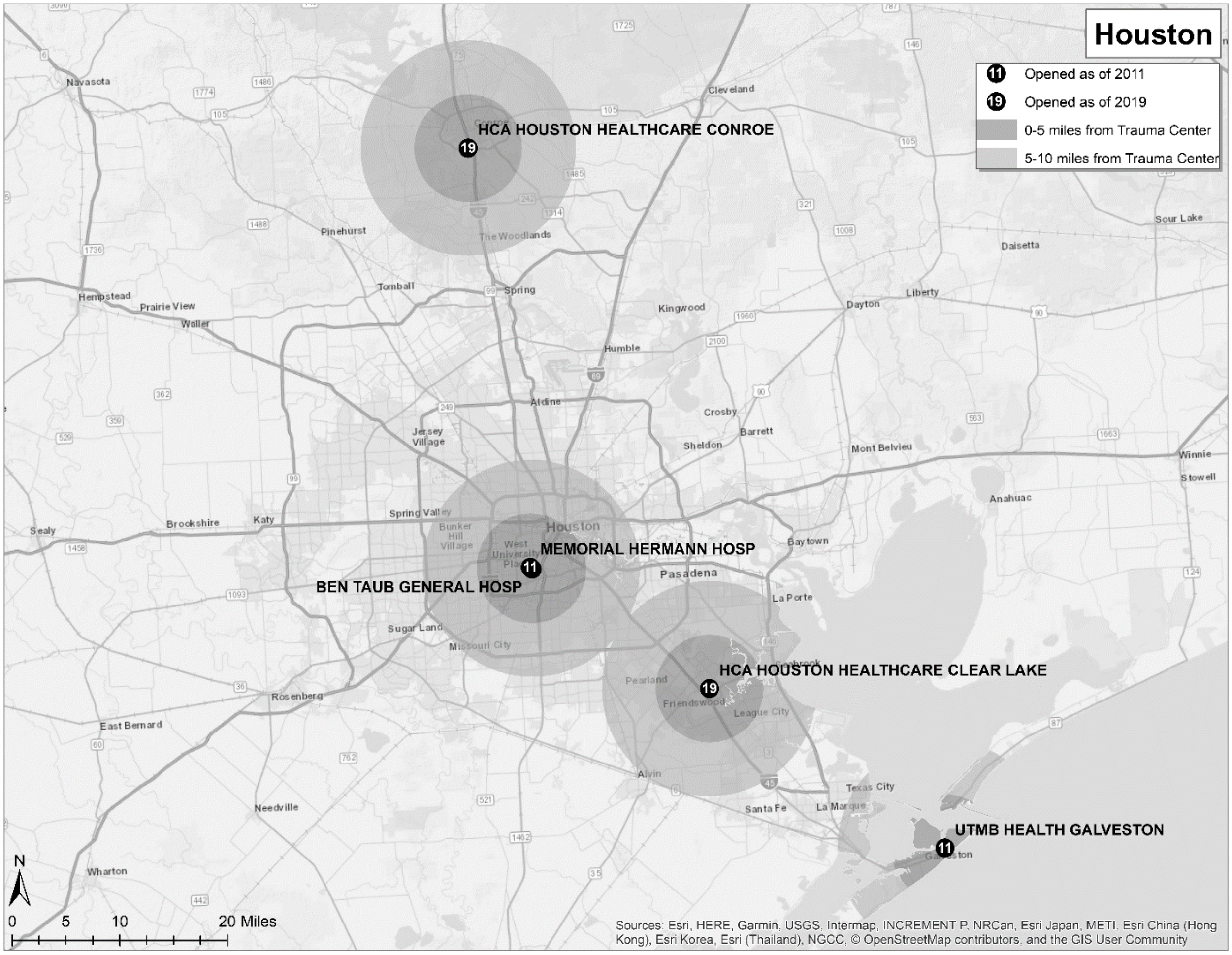
Cohort selection based on patients having one or more of the following:
Trauma Activation Fee revenue code: 068x
Trauma-related DRG codes: 025-027, 082-087, 183-185, 913-914, 955-959, 963-965
Trauma-related ICD-9 codes with an urgent/emergent admission: 800-959; excluding 930-939 and 905-909
Trauma-related ICD-10 codes with an urgent/emergent admission: All ICD-10 codes which map to the above listed ICD-9 codes using General Equivalence Mappings as a crosswalk.

Source: Centers for Medicare & Medicaid Services.
ICD-10-CM and ICD-10 PCS and GEMs Archive.
ICD-10. Published March 14, 2022. Accessed June 14, 2022.
https://www.cms.gov/Medicare/Coding/ICD10/Archive-ICD-10-CM-ICD-10-PCS-GEMs

Appendix Figure 1: Maps of Trauma Centers in Austin, Dallas-Fort Worth, and Houston in 2011 and 2019




Dallas
Opened as of 2011
Opened as of 2019
0-5 miles from Trauma Center
5-10 miles from Trauma Center
MEDICAL CITY DENTON
TX HLTH PRESBYTERIAN HOSP PLANO
MEDICAL CITY PLANO
BS&W MED CTR GRAPEVINE
TX HLTH PRESBYTERIAN HOSP DALLAS
PARKLAND HOSP
BAYLOR UNIV MED CTR
METHODIST DALLAS MED CTR
TX HLTH HARRIS METHODIST HOSP FW
JOHN PETER SMITH HOSP
MEDICAL CITY ARLINGTON
N
0
5
10
20 Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community


Houston
Opened as of 2011
Opened as of 2019
0-5 miles from Trauma Center
5-10 miles from Trauma Center
HCA HOUSTON HEALTHCARE CONROE
MEMORIAL HERMANN HOSP
BEN TAUB GENERAL HOSP
HCA HOUSTON HEALTHCARE CLEAR LAKE
UTMB HEALTH GALVESTON
Navasota
Cleveland
Pinehurst
The Woodlands
Sour Lake
Daisetta
Tomball
Spring
Hempstead
Prairie View
Waller
Kingwood
Dayton
Liberty
Humble
Aldine
Crosby
Barrett
Jersey Village
Sheldon
Mont Belvieu
Winnie
Stowell
Anahuac
Sealy
Brookshire
Katy
Spring Valley
Houston
Baytown
Pasadena
La Porte
Sugar Land
Missouri City
Pearland
Friendswood
League City
Rosenberg
East Bernard
Alvin
Texas City
Santa Fe
La Marque
Needville
Wharton
N
0 5 10 20 Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

Appendix Table 2: Effect of Trauma Verification on Outcomes by Severity Score and Year, 2011-2019

	Spending				**Readmissions**				**Mortality**			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Pre-upgrade	-0.215***		-0.229***		0.00687*		0.0127		0.00144		-0.00462	
Upgraded	0.0982*		0.0262		0.00610		0.00138		0.00236		-0.00130	
Interactions with year:		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*
Upgraded * 2016	-0.384***	-0.286***	0.0206	0.0467	0.00878	0.0149	-0.0151	-0.0137	-0.00481	-0.00238	0.00126	-3.48e-05
Upgraded * 2017	-0.193**	-0.0952*	-0.000178	0.0260	0.00817	0.0143	0.0118	0.0132	0.00190	-0.00245	0.00140	9.98e-05
Upgraded * 2018	-0.170**	-0.0722	-0.00266	0.0235	-0.00207	0.00403	-0.000431	0.000951		0.00426*	0.00118	-0.000110
Upgraded * 2019		0.0982*		0.0262		0.00610		0.00138		0.00236		-0.00130
Injury Body Region:												
Head/neck	0.0787***		0.0889***		0.00130		0.00299		-0.000701		0.00831***	
Chest	0.0295		0.0150		-0.00727		-0.00301		0.00150		-0.00399*	
Abdominal & pelvic content	-0.0368		0.106***		-0.000846		0.0143*		-0.00229*		0.00106	
Extremities & pelvic girdle	-0.0118		0.151***		-0.00510		0.00718		-0.00210*		-0.00551**	
Face	0.00226		-0.0383		-0.00183		-0.00858		-0.00166		-0.00761*	
External	-0.0585***		-0.0245		-0.00145		-0.00768		-0.000626		-0.00346	
Wage Index	7.440***		2.187***									
MSA:												
Dallas/Fort Worth	0.201***		0.116***		-0.00785**		-0.00471		0.00166*		0.00182	
Houston	-0.197***		-0.0486*		-0.0112**		-0.00502		0.00111		-0.00138	
Charlson Index:												
1 to 2	0.000771		0.0561***		0.00689**		0.0339***		-0.000472		-0.00784***	
3 to 4	0.0439		0.117***		0.0336***		0.0883***		-0.000312		-0.0133***	
5+	0.0790**		0.146***		0.0607***		0.135***		0.00192		-0.00375	
Male	0.0464***		0.0178		-0.00365		-0.00615		0.00149*		0.00242	
Transfer In	0.00729		-0.0184		0.0127		0.0148		0.00490		-0.00197	
Transfer Out	-0.265		0.0610		0.155***		0.326***		-0.00163		-0.00784	
Age:												
26 to 35	0.0285		-0.00647		-0.00235		0.00192		0.000445		0.00146	
36 to 45	0.0138		-0.0317		-0.00439		0.00398		0.000787		0.00560*	

46 to 55	0.0200	-0.0593**	0.000375	0.00748	0.000932	0.00670**
56 to 64	0.00831	-0.108***	-0.00270	0.00259	0.000627	0.00950***
Length of Stay:						
1	0.0843	-0.224*	0.0112	0.0257		
2 to 5	0.538***	0.217*	0.0276*	0.0411		
6 to 9	1.109***	0.777***	0.0694***	0.0635*		
10+	2.034***	1.653***	0.135***	0.146***		
Outpatient	-0.752***	-0.926***	-0.0154	0.0107		
NISS:						
2 to 3	0.0632***		-0.00589		-0.00306***	
4	0.138***		0.00183		-0.00285**	
5 to 8	0.210***		-0.00763*		-0.00206*	
12 to 15		0.0532**		-0.00666		-0.00382
16 to 24		0.244***		-0.00380		0.00284
25+		0.592***		0.0127		0.0183***
Year:						
2011	-0.126***	-0.0538	0.00249	-0.00718	-0.00157	0.00681
2012	-0.192***	-0.0294	0.00114	0.0108	-0.00108	0.00365
2013	-0.161***	-0.0348	-0.00246	0.00842	-0.00126	0.00399
2014	-0.0841**	-0.0402	-0.00140	-0.0169	-0.00172	0.00527
2015	-0.00501	-0.00441	0.00113	0.00639	0.0000524	-0.000753
2016	0.0839**	0.132	0.00704	0.00365	-0.000333	0.00321
2017	0.0510	0.0883	0.00223	0.000469	-0.000388	0.00222
2018	0.0547	0.0461	-0.0000936	0.00878	-0.00130	-0.00306
2019	---					
Constant	2.260***	7.757***	0.0229	-0.0209	0.00303	0.00337
N	19,334	14,251	19,334	14,251	19,334	14,251

*** p<0.001, ** p<0.01, * p<0.05
All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Transfer In/Out, Age groups, and MSA.
Spending and readmission regressions also include Length of Stay groups and Outpatient.
Spending regressions also include Wage Index.
NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 3: Effect of Trauma Verification on Outcomes by Severity Score and Hospital, 2011-2019

	Spending				Readmissions				Mortality			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Upgraded Trauma Centers:		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*
Hospital A	-0.0582	0.0502	-0.367***	-0.334***	0.0267*	0.0209	-0.0258	-0.0189	0.00514	-0.00139	-0.00517	0.00390
Hospital A* Upgraded	0.108		0.0328		-0.00587		0.00694		-0.00653		0.00907	
Hospital B	-0.143**	-0.227	-0.322***	-0.591***	0.0104	0.0158	0.0103	0.0228	-0.00210	-0.00310	-0.00428	-0.00881
Hospital B* Upgraded	-0.0834		-0.268		0.00535		0.0125		-0.000993		-0.00453	
Hospital C	-0.136**	0.0956	-0.132*	-0.0171	-0.000553	-0.00963	0.0105	0.0102	0.00324	-0.00132	-0.00124	0.0143
Hospital C* Upgraded	0.231**		0.115		-0.00908		-0.000292		-0.00456		0.0155	
Hospital D	-0.121	0.214***	0.0720	0.101	0.0160	0.00763	0.0353	-0.0383*	-0.00132	0.00184	0.00279	-0.00284
Hospital D* Upgraded	0.335***		0.0290		-0.00832		-0.0736**		0.00316		-0.00563	
Hospital E	-0.365***	-0.261**	-0.549***	-0.313***	0.00558	-0.00961	0.0317	0.00558	-0.00127	0.0242***	-0.0111	-0.00195
Hospital E* Upgraded	0.104		0.236*		-0.0152		-0.0262		0.0255***		0.00917	
Hospital F	-0.468***	-0.231**	-0.200***	-0.193**	0.000477	-0.0117	0.0193	0.0231	0.00466*	0.00539	-0.00470	0.000396
Hospital F* Upgraded	0.237**		0.00715		-0.0122		0.00386		0.000724		0.00510	
Hospital G	0.0370	0.276***	0.0609	0.287***	0.0103	-0.00678	0.0237	0.0229	-0.00118	-0.00237	-0.0111	-0.00678
Hospital G* Upgraded	0.239**		0.226*		-0.0171		-0.000822		-0.00119		0.00434	
Hospital H	-0.279***	-0.0524	-0.523***	-0.312***	0.00767	0.0214*	-0.00468	0.0142	0.00197	0.00299	-0.00496	0.00326
Hospital H* Upgraded	0.226**		0.211*		0.0137		0.0189		0.00103		0.00822	
Hospital I	-0.510***	-0.173***	0.125	0.347***	-0.00577	0.0133***	0.0631	0.00627	-0.00100	-0.00117	-0.0158	0.000852
Hospital I* Upgraded	0.336**		0.222		0.0191		-0.0568		-0.000168		0.0166	
Injury Body Region:												
Head/neck	0.0832***		0.0853***		0.00142		0.00261		-0.000742		0.00840***	
Chest	0.0360		0.0168		-0.00711		-0.00287		0.00138		-0.00400*	
Abdominal & pelvic content	-0.0306		0.107***		-0.000768		0.0147*		-0.00251*		0.00111	
Extremities & pelvic girdle	-0.0146		0.154***		-0.00508		0.00754		-0.00206*		-0.00543**	
Face	-0.000152		-0.0394		-0.00178		-0.00867		-0.00165		-0.00768**	
External	-0.0548***		-0.0286		-0.00151		-0.00728		-0.000686		-0.00343	
Wage Index	7.198***		-0.868									
MSA:												

Dallas/Fort Worth	0.217***	0.112***	-0.00882**	-0.00599	0.00172*	0.00346
Houston	-0.182***	0.0831**	-0.0152***	-0.00241	0.000761	-0.000543
Charlson Index:						
1 to 2	0.00394	0.0531***	0.00694**	0.0335***	-0.000465	-0.00783***
3 to 4	0.0423	0.117***	0.0334***	0.0884***	-0.000274	-0.0134***
5+	0.0797**	0.146***	0.0605***	0.135***	0.00191	-0.00384
Male	0.0482***	0.0189	-0.00375	-0.00586	0.00150*	0.00236
Transfer In	0.0192	-0.0390	0.0120	0.0148	0.00508	-0.00218
Transfer Out	-0.251	0.0631	0.155***	0.326***	-0.00193	-0.00756
Age:						
26 to 35	0.0220	-0.00957	-0.00243	0.00227	0.000500	0.00148
36 to 45	0.00640	-0.0226	-0.00442	0.00408	0.000817	0.00565*
46 to 55	0.0124	-0.0583**	0.000279	0.00752	0.000966	0.00682**
56 to 64	-0.000942	-0.109***	-0.00291	0.00269	0.000671	0.00947***
Length of Stay:						
1	0.0642	-0.224*	0.0109	0.0249		
2 to 5	0.517***	0.210*	0.0273*	0.0404		
6 to 9	1.086***	0.772***	0.0691***	0.0626*		
10+	2.025***	1.657***	0.135***	0.145***		
Outpatient	-0.773***	-0.900***	-0.0160	0.0111		
NISS:						
2 to 3	0.0684***		-0.00566		-0.00305***	
4	0.131***		0.00186		-0.00276**	
5 to 8	0.207***		-0.00736*		-0.00201*	
12 to 15		0.0537**		-0.00652		-0.00388
16 to 24		0.238***		-0.00363		0.00281
25+		0.587***		0.0127		0.0183***
Year:						
2012	-0.0571*	0.0375	-0.00228	0.0153	0.000412	-0.00287
2013	-0.0248	0.0652*	-0.00598	0.0122	0.000194	-0.00263
2014	0.0400	0.0286	-0.00496	-0.0119	-0.000217	-0.00141
2015	0.110***	0.0246	-0.00347	0.0108	0.00139	-0.00757*
2016	0.190***	0.163***	0.00376	0.00712	0.000985	-0.00390
2017	0.152***	0.135***	-0.000122	0.00852	0.000436	-0.00499
2018	0.153***	0.117***	-0.00352	0.0138	0.000848	-0.0106**
2019	0.154***	0.0792*	-0.00260	0.00410	0.00194	-0.00798*
Constant	2.381***	10.62***	0.0278*	-0.0260	0.00154	0.00927

N	19,334	14,251	19,334	14,251	19,334	14,251

*** p<0.001, ** p<0.01, * p<0.05
All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Outpatient, Transfer In/Out, Age groups, and MSA.
Spending and readmission regressions also include Length of Stay groups and Outpatient.
Spending regressions also include Wage Index.
NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 4: Effect of Trauma Verification on Outcomes by Severity Score and Year using ISS, 2011-2019

	Spending				**Readmissions**				**Mortality**			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Pre-upgrade	-0.211***		-0.251***		0.0105**		0.00712		0.000905		-0.00587	
Upgraded	0.0867*		0.0356		0.00317		0.00522		0.00179		-0.00162	
Interactions with year:		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*
Upgraded * 2016	-0.371***	-0.284***	0.103	0.138*	0.00587	0.00904	-0.0157	-0.0105	-0.00414	-0.00235	0.00185	0.000225
Upgraded * 2017	-0.168**	-0.0812*	-0.0142	0.0213	0.00678	0.00995	0.0148	0.0200	-0.00431	-0.00252	0.00188	0.000258
Upgraded * 2018	-0.144**	-0.0575	-0.0255	0.0101	0.00380	0.00696	-0.0113	-0.00612	0.00157	0.00336	0.00111	-0.00051
Upgraded * 2019		0.0867*		0.0356		0.00317		0.00522		0.00179		-0.00162
Injury Body Region:												
Head/neck	0.0514**		-0.00384		-0.000364		0.00184		-0.000174		0.00784**	
Chest	-0.0304		-0.0508**		-0.00596		-0.00685		0.000899		-0.00502*	
Abdominal & pelvic content	-0.0401		0.00331		0.00163		0.0101		-0.00156		-0.000571	
Extremities & pelvic girdle	-0.0224		0.107***		-0.00575		0.00803		-0.00178		-0.00778**	
Face	-0.0292		-0.110***		-0.00242		-0.0137		-0.00147		-0.00999**	
External	-0.0812***		-0.0704***		-0.00462		-0.00623		-0.000389		-0.00544*	
Wage Index	7.006***		1.582**									
MSA:												
Dallas/Fort Worth	0.192***		0.113***		-0.00812**		-0.00439		0.00143*		0.00232	
Houston	-0.191***		-0.00206		-0.0121***		-0.00290		0.00104		-0.00113	
Charlson Index:												
1 to 2	0.00904		0.0637***		0.00975***		0.0353***		-0.000677		-0.00869***	
3 to 4	0.0238		0.155***		0.0361***		0.0950***		-0.000510		-0.0150***	
5+	0.0566*		0.183***		0.0693***		0.137***		0.00159		-0.00443	
Male	0.0484***		0.0189		-0.00396		-0.00628		0.00142*		0.00329	
Transfer In	0.0148		-0.0311		0.00219		0.0220		0.00309		-0.00230	
Transfer Out	-0.158		0.0725		0.159***		0.344***		-0.00159		-0.00895	
Age:												
26 to 35	0.0211		0.00383		-0.00151		0.000768		0.000895		0.000708	
36 to 45	0.0147		-0.0423		-0.00150		-0.000329		0.000744		0.00648*	
46 to 55	0.0180		-0.0686**		0.00186		0.00659		0.00115		0.00734*	

56 to 64	0.00190	-0.129***	-0.000344	-0.000125	0.000975	0.0103***
Length of Stay:						
1	0.0465	-0.234*	0.0107	0.0256		
2 to 5	0.508***	0.196*	0.0259*	0.0415		
6 to 9	1.074***	0.767***	0.0656***	0.0617		
10+	1.970***	1.657***	0.118***	0.152***		
Outpatient	-0.777***	-0.936***	-0.0149	0.0117		
ISS:						
2 to 3	0.0477*		-0.00348		-0.00212	
4	0.133***		-0.00182		-0.00109	
5 to 8	0.248***		-0.00413		-0.00147	
12 to 15		0.112***		0.00141		-0.00274
16 to 24		0.394***		0.00395		0.00684*
25+		0.606***		0.0115		0.0184***
Year:						
2011	-0.133***	-0.0615	0.000628	-0.00396	-0.0000288	0.00529
2012	-0.178***	-0.0471	0.000896	0.0143	-0.000924	0.00415
2013	-0.152***	-0.0537	0.000422	0.00677	-0.00107	0.00431
2014	-0.0873**	-0.0556	0.000274	-0.0215	-0.00106	0.00517
2015	-0.00115	-0.0306	0.00199	0.00739	0.000114	-0.00124
2016	0.101***	0.112**	0.00900	-0.000308	-0.000223	0.00361
2017	0.0406	0.116**	0.00566	-0.00561	0.000125	0.00164
2018	0.0372	0.0704	-0.000522	0.0130	-0.00114	-0.00405
2019						
Constant	2.76***	8.509***	0.0202	-0.0209	0.00147	0.00613
N	21,946	11,639	21,946	11,639	21,946	11,639

*** p<0.001, ** p<0.01, * p<0.05
All regressions include year fixed effects, ISS groups, Injury Body Region, Charlson Index groups, Gender, Transfer In/Out, Age groups, and MSA.
Spending and readmission regressions also include Length of Stay groups and Outpatient.
Spending regressions also include Wage Index.
ISS= Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 5: Effect of Trauma Verification on Outcomes by Severity Score and Hospital using ISS, 2011-2019

	Spending				Readmissions				Mortality			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Upgraded Trauma Centers:		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*
Hospital A	-0.102	-0.00386	-0.387***	-0.355***	0.0299**	0.0147	-0.0474	-0.0218	0.00409	-0.00138	-0.00699	0.00493
Hospital A* Upgraded	0.0980		0.0326		-0.0151		0.0256		-0.00547		0.0119	
Hospital B	-0.174***	-0.229	-0.296***	-0.782***	0.0112	0.0112	0.0120	0.0336	-0.00213	-0.00273	-0.00497	-0.0121
Hospital B* Upgraded	-0.0555		-0.486**		-5.10e-05		0.0216		-0.000598		-0.00715	
Hospital C	-0.0904*	0.0750	-0.240***	0.00589	0.00548	-0.00621	-0.000559	0.00708	0.00233	-0.00130	-0.00102	0.0182
Hospital C* Upgraded	0.165*		0.246*		-0.0117		0.00763		-0.00363		0.0192	
Hospital D	-0.0940	0.210***	0.0660	0.0457	0.0204	8.22e-05	0.0354	-0.0402	-0.00146	0.00131	0.00278	-0.00424
Hospital D* Upgraded	0.304***		-0.0202		-0.0203		-0.0756*		0.00278		-0.00702	
Hospital E	-0.395***	-0.225**	-0.575***	-0.368***	0.0110	-0.000308	0.0321	0.00303	-0.00156	0.0186***	-0.0144	-0.00227
Hospital E* Upgraded	0.171		0.207		-0.0113		-0.0291		0.0202***		0.0122	
Hospital F	-0.426***	-0.230***	-0.221***	-0.188*	0.00270	-0.00151	0.0172	0.0184	0.00382*	0.00418	-0.00571	0.000488
Hospital F* Upgraded	0.196**		0.0331		-0.00421		0.00120		0.000366		0.00620	
Hospital G	0.0649	0.296***	-0.00107	0.266**	0.0187*	0.00416	0.00950	0.00934	-0.00144	-0.00228	-0.0141	-0.00934
Hospital G* Upgraded	0.231***		0.267**		-0.0146		-0.000164		-0.000833		0.00478	
Hospital H	-0.329***	-0.113*	-0.484***	-0.299***	0.00828	0.0152	-0.00851	0.0249	0.00150	0.00225	-0.00730	0.00315
Hospital H* Upgraded	0.216**		0.185		0.00688		0.0334		0.000750		0.0105	
Hospital I	-0.409***	-0.119***	0.108	0.372***	-0.00639	0.0113**	0.0999	0.00825	-0.00220	-0.00134	-0.0179	0.00118
Hospital I* Upgraded	0.290**		0.264		0.0177		-0.0916		0.000862		0.0190	
Injury Body Region:												
Head/neck	0.0525**		-0.00745		-0.000176		0.00153		-0.000173		0.00796**	
Chest	-0.0268		-0.0487**		-0.00562		-0.00687		0.000834		-0.00501*	
Abdominal & pelvic content	-0.0371		0.00256		0.00176		0.0105		-0.00168		-0.000515	
Extremities & pelvic girdle	-0.0267		0.111***		-0.00567		0.00850		-0.00174		-0.00769**	
Face	-0.0339		-0.110***		-0.00236		-0.0141		-0.00138		-0.0100**	
External	-0.0782***		-0.0761***		-0.00453		-0.00593		-0.000406		-0.00539	
Wage Index	6.315***		-1.360*									
MSA:												
Dallas/Fort Worth	0.208***		0.102***		-0.00882**		-0.00660		0.00149		0.00439	

Houston	-0.145***	0.115***	-0.0146***	-0.00105	0.000745	7.33e-05
Charlson Index:						
1 to 2	0.0108	0.0625***	0.00983***	0.0348***	-0.000662	-0.00872***
3 to 4	0.0204	0.155***	0.0358***	0.0949***	-0.000487	-0.0151***
5+	0.0585*	0.184***	0.0692***	0.137***	0.00154	-0.00460
Male	0.0508***	0.0201	-0.00399	-0.00610	0.00144*	0.00320
Transfer In	0.0204	-0.0588	0.00203	0.0213	0.00320	-0.00264
Transfer Out	-0.135	0.0666	0.159***	0.344***	-0.00195	-0.00840
Age:						
26 to 35	0.0142	0.00734	-0.00162	0.00123	0.000964	0.000730
36 to 45	0.00857	-0.0301	-0.00157	-0.000358	0.000793	0.00654*
46 to 55	0.0114	-0.0665**	0.00172	0.00664	0.00118	0.00750**
56 to 64	-0.00636	-0.127***	-0.000531	-0.000204	0.00101	0.0103***
Length of Stay:						
1	0.0285	-0.236*	0.0102	0.0246		
2 to 5	0.490***	0.185	0.0252*	0.0413		
6 to 9	1.057***	0.758***	0.0649***	0.0611		
10+	1.963***	1.658***	0.117***	0.152***		
Outpatient	-0.794***	-0.907***	-0.0154	0.0128		
ISS:						
2 to 3	0.0526*		-0.00333		-0.00220	
4	0.129***		-0.00191		-0.00100	
5 to 8	0.248***		-0.00413		-0.00149	
12 to 15		0.108***		0.00137		-0.00288
16 to 24		0.388***		0.00366		0.00680*
25+		0.603***		0.0118		0.0185***
Year:						
2012	-0.0376	0.0321	-0.000608	0.0153	-0.000871	-0.000972
2013	-0.00106	0.0544	-0.00228	0.00898	-0.00106	-0.000868
2014	0.0472	0.0227	-0.00219	-0.0184	-0.00105	-3.86e-05
2015	0.115***	0.0156	-0.00125	0.00918	2.78e-05	-0.00663
2016	0.211***	0.164***	0.00648	0.00112	-0.000342	-0.00211
2017	0.149***	0.178***	0.00398	0.00165	-0.000447	-0.00421
2018	0.150***	0.149***	-0.00231	0.0137	-0.000496	-0.0103*
2019	0.163***	0.0989**	-0.00279	0.00347	0.000426	-0.00675
Constant	3.299***	11.256***	0.0238	-0.0231	0.00141	0.0103

N	21,946	11,639	21,946	11,639	21,946	11,639

*** p<0.001, ** p<0.01, * p<0.05

All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Transfer In/Out, Age groups, and MSA.

Spending and readmission regressions also include Length of Stay groups and Outpatient.

Spending regressions also include Wage Index.

ISS= Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 6: Effect of Trauma Verification on Outcomes by Severity Score and Year without Transfer Patients, 2011-2019

	Spending				**Readmissions**				**Mortality**			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Pre-upgrade	-0.214***		-0.235***		0.00755*		0.0119		0.00140		-0.00441	
Upgraded	0.0934*		0.0155		0.00485		0.00402		0.00324		-0.00135	
Interactions with year:		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*
Upgraded * 2016	-0.380***	-0.287***	0.0332	0.0488	0.0121	0.0.169	-0.0242	-0.0202	-0.00567	-0.00243	0.00224	0.000888
Upgraded * 2017	-0.193**	-0.100*	0.0201	0.0356	0.00915	0.014	0.0122	0.0162	-0.00575	-0.00251	0.00162	0.000269
Upgraded * 2018	-0.165**	-0.0715	0.000965	0.0165	-0.00103	0.000382	-0.000459	0.00356	0.00103	0.00427*	0.00214	0.000793
Upgraded * 2019		0.0934*		0.0155		0.00485		0.00402		0.00324		-0.00135
Injury Body Region:												
Head/neck	0.0787***		0.0902***		0.00140		0.00477		-0.000929		0.00820***	
Chest	0.0277		0.0142		-0.00832*		-0.00411		0.00170		-0.00455*	
Abdominal & pelvic content	-0.0388		0.106***		-0.000736		0.0148*		-0.00216*		0.00129	
Extremities & pelvic girdle	-0.0128		0.150***		-0.00579*		0.00779		-0.00197*		-0.00619**	
Face	0.00513		-0.0416		-0.00284		-0.00651		-0.00154		-0.00865**	
External	-0.0590***		-0.0342		-0.00177		-0.00759		-0.000581		-0.00362	
Wage Index	7.416***		1.949***									
MSA:												
Dallas/Fort Worth	0.201***		0.123***		-0.00788**		-0.00473		0.00167*		0.00215	
Houston	-0.197***		-0.0402		-0.0121***		-0.00430		0.00117		-0.000888	
Charlson Index:												
1 to 2	0.000162		0.0528***		0.00623*		0.0327***		-0.000455		-0.00783***	
3 to 4	0.0415		0.116***		0.0340***		0.0847***		-0.00126		-0.0129***	
5+	0.0751*		0.151***		0.0616***		0.134***		0.00198		-0.00277	
Male	0.0452***		0.0177		-0.00355		-0.00554		0.00138*		0.00256	
Age:												
26 to 35	0.0281		-0.00138		-0.00167		0.00162		0.000456		0.00145	
36 to 45	0.0148		-0.0292		-0.00355		0.00298		0.000819		0.00560*	

46 to 55	0.0216	-0.0597**	0.00134	0.00796	0.000749	0.00673**
56 to 64	0.0106	-0.111***	-0.00167	0.00234	0.000783	0.00840**
Length of Stay:						
1	0.0836	-0.219*	0.0104	0.0244		
2 to 5	0.536***	0.210*	0.0276*	0.0408		
6 to 9	1.116***	0.769***	0.0661***	0.0644*		
10+	2.031***	1.648***	0.134***	0.146***		
Outpatient	-0.752***	-0.928***	-0.0155	0.0104		
NISS:						
2 to 3	0.0638***		-0.00566		-0.00311***	
4	0.137***		0.00259		-0.00321***	
5 to 8	0.212***		-0.00615		-0.00212*	
12 to 15		0.0595**		-0.00652		-0.00388
16 to 24		0.246***		-0.00525		0.00274
25+		0.595***		0.00927		0.0182***
Year:						
2011	-0.124***	-0.0699*	0.00159	-0.00808	-0.000720	0.00591
2012	-0.191***	-0.0378	0.000931	0.0113	-0.000256	0.00368
2013	-0.160***	-0.0363	-0.00373	0.00851	-0.000409	0.00397
2014	-0.0847**	-0.0360	-0.00130	-0.0156	-0.000845	0.00532
2015	-0.00423	-0.0110	0.000743	0.00734	0.000912	-0.000997
2016	0.0849**	0.128***	0.00562	0.00448	0.000524	0.00253
2017	0.0512	0.0774*	0.00143	0.00256	0.000459	0.00207
2018	0.0563	0.0397	-0.000925	0.00598	-0.000462	-0.00412
2019						
Constant	2.28***	7.99***	0.0232	-0.0209	0.00239	0.00403
N	19,156	13,794	19,156	13,794	19,156	13,794

*** p<0.001, ** p<0.01, * p<0.05
All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Age groups, and MSA.
Spending and readmission regressions also include Length of Stay groups and Outpatient.
Spending regressions also include Wage Index.
NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 7: Effect of Trauma Verification on Outcomes by Severity Score and Hospital without Transfer Patients, 2011-2019

	Spending				**Readmissions**				**Mortality**			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
Upgraded Trauma Centers:	Regression	Marginal Effects *Hospital + (Hospital * Upgraded):*	Regression	Marginal Effects *Hospital + (Hospital * Upgraded):*	Regression	Marginal Effects *Hospital + (Hospital * Upgraded):*	Regression	Marginal Effects *Hospital + (Hospital * Upgraded):*	Regression	Marginal Effects *Hospital + (Hospital * Upgraded):*	Regression	Marginal Effects *Hospital + (Hospital * Upgraded):*
Hospital A	-0.0635	0.0500	-0.365***	-0.340***	0.0301**	0.0257	-0.0268	-0.0167	0.00508	-0.00129	-0.00551	0.00401
Hospital A* Upgraded	0.113		0.0251		-0.00444		0.0101		-0.00637		0.00952	
Hospital B	-0.144**	-0.224	-0.328***	-0.576***	0.0103	0.0157	0.0112	0.00341	-0.00206	-0.00261	-0.00411	-0.00879
Hospital B* Upgraded	-0.0804		-0.247		0.00542		-0.00776		-0.000548		-0.00469	
Hospital C	-0.133**	0.0997	-0.127*	-0.0159	-0.00245	-0.00882	0.0107	0.0110	0.00319	-0.000982	-0.000409	0.0150
Hospital C* Upgraded	0.233**		0.112		-0.00637		0.000310		-0.00418		0.0155	
Hospital D	-0.111	0.217***	0.0345	0.122*	0.0167	0.00799	0.0327	-0.0368*	-0.00120	0.00206	0.00307	-0.00228
Hospital D* Upgraded	0.327***		0.0880		-0.00872		-0.0695*		0.00326		-0.00535	
Hospital E	-0.351***	-0.261**	-0.569***	-0.317***	0.00915	-0.00969	0.0300	0.00646	-0.00122	0.0245***	-0.0109	-0.00170
Hospital E* Upgraded	0.0900		0.252*		-0.0188		-0.0235		0.0257***		0.00916	
Hospital F	-0.470***	-0.248**	-0.190***	-0.191**	0.00113	-0.0105	0.0182	0.0282	0.00461*	0.00568	-0.00471	0.000938
Hospital F* Upgraded	0.222**		-0.000125		-0.0116		0.00999		0.00106		0.00565	
Hospital G	0.0370	0.279***	0.0591	0.290***	0.0102	-0.00605	0.0257	0.0232	-0.00116	-0.00211	-0.0111	-0.00648
Hospital G* Upgraded	0.242**		0.231*		-0.0163		-0.00250		-0.000946		0.00467	
Hospital H	-0.278***	-0.0543	-0.534***	-0.317***	0.00976	0.0208*	-0.00837	0.0192	0.00184	0.00326	-0.00494	0.00339
Hospital H* Upgraded	0.224**		0.216*		0.0110		0.0276		0.00142		0.00834	
Hospital I	-0.498***	-0.176***	0.125	0.349***	-0.00503	0.0127**	0.0683	0.00516	-0.000966	-0.00110	-0.0160	0.00125
Hospital I* Upgraded	0.322**		0.223		0.0177		-0.0632		-0.000135		0.0173	
Injury Body Region:												
Head/neck	0.0834***		0.0873***		0.00153		0.00428		-0.000972		0.00830***	
Chest	0.0340		0.0172		-0.00818*		-0.00410		0.00158		-0.00455*	
Abdominal & pelvic content	-0.0327		0.107***		-0.000694		0.0152**		-0.00237*		0.00135	
Extremities & pelvic girdle	-0.0159		0.153***		-0.00581*		0.00814		-0.00192*		-0.00611**	
Face	0.00285		-0.0410		-0.00280		-0.00650		-0.00152		-0.00873**	
External	-0.0555***		-0.0373*		-0.00187		-0.00716		-0.000632		-0.00357	
Wage Index	7.187***		-1.149*									
MSA:												

Dallas/Fort Worth	0.217***	0.121***	-0.00893**	-0.00603	0.00172*	0.00390
Houston	-0.181***	0.0948***	-0.0168***	-0.00162	0.000839	8.42e-05
Charlson Index:						
1 to 2	0.00311	0.0510***	0.00625*	0.0323***	-0.000448	-0.00782***
3 to 4	0.0394	0.116***	0.0338***	0.0847***	-0.00121	-0.0130***
5+	0.0754**	0.152***	0.0614***	0.134***	0.00196	-0.00287
Male	0.0468***	0.0187	-0.00368	-0.00522	0.00140*	0.00248
Transfer In						
Transfer Out						
Age:						
26 to 35	0.0216	-0.00465	-0.00171	0.00213	0.000508	0.00147
36 to 45	0.00804	-0.0207	-0.00357	0.00316	0.000844	0.00565*
46 to 55	0.0144	-0.0586**	0.00123	0.00806	0.000781	0.00686**
56 to 64	0.00160	-0.112***	-0.00185	0.00254	0.000820	0.00839**
Length of Stay:						
1	0.0625	-0.217*	0.0103	0.0238		
2 to 5	0.515***	0.204*	0.0274*	0.0400		
6 to 9	1.091***	0.763***	0.0658***	0.0634*		
10+	2.021***	1.651***	0.134***	0.145***		
Outpatient	-0.775***	-0.902***	-0.0160	0.0107		
NISS:						
2 to 3	0.0692***		-0.00540		-0.00310***	
4	0.130***		0.00258		-0.00311**	
5 to 8	0.210***		-0.00589		-0.00207*	
12 to 15		0.0602***		-0.00633		-0.00394
16 to 24		0.239***		-0.00494		0.00271
25+		0.588***		0.00925		0.0182***
Year:						
2012	-0.0576*	0.0439	-0.00163	0.0165	0.000384	-0.00201
2013	-0.0257	0.0779*	-0.00634	0.0120	0.000191	-0.00183
2014	0.0385	0.0444	-0.00394	-0.0109	-0.000203	-0.000549
2015	0.109***	0.0316	-0.00303	0.0120	0.00139	-0.00696
2016	0.190***	0.174***	0.00343	0.00786	0.000986	-0.00370
2017	0.150***	0.139***	1.70e-05	0.0113	0.000406	-0.00435
2018	0.154***	0.123***	-0.00353	0.0117	0.000792	-0.0107**
2019	0.149***	0.0908**	-0.00229	0.00532	0.00131	-0.00733

Constant	2.396***	10.878***	0.0275*	-0.0264	0.00174	0.00901
N	19,156	13,794	19,156	13,794	19,156	13,794

*** p<0.001, ** p<0.01, * p<0.05
All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Age groups, and MSA.
Spending and readmission regressions also include Length of Stay groups and Outpatient.
Spending regressions also include Wage Index.
NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 8: Effect of Trauma Verification on Outcomes by Severity Score and Year using Pursuit Dates, 2011-2019

	Spending				Readmissions				Mortality			
	NISS <9		NISS 9+		NISS <9		NISS 9+		NISS <9		NISS 9+	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Pre-upgrade	-0.227***		-0.318***		0.0106*		0.0173		9.26e-05		-0.00841	
Upgraded	0.143**		-0.150***		-0.00511		-0.00210		0.00118		-0.000860	
Interactions with year:		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*
Upgraded * 2016	-0.277***	-0.134**	-0.0718	-0.222***	0.0131	0.00798	0.00889	0.00679	0.00544	0.00662**	0.00105	0.000188
Upgraded * 2017	-0.229***	-0.865*	-0.0912	-0.241***	0.0136	0.00847	0.0171	0.0150	0.00161	0.00279	-0.000812	-0.00167
Upgraded * 2018	-0.149*	-0.00623	-0.0254	-0.175***	0.00138	-0.00373	0.00801	0.00591	0.00383	0.00501*	-0.00113	-0.00199
Upgraded * 2019		0.143**		-0.150***		-0.00511		-0.00210		0.00118		-0.000860
Injury Body Region:												
Head/neck	0.0733***		0.0921***		0.00156		0.00288		-0.000702		0.00839***	
Chest	0.0258		0.0178		-0.00685		-0.00305		0.00141		-0.00393*	
Abdominal & pelvic content	-0.0423*		0.108***		-0.000711		0.0144*		-0.00238*		0.00105	
Extremities & pelvic girdle	-0.0141		0.158***		-0.00511		0.00738		-0.00206*		-0.00551**	
Face	0.00283		-0.0397		-0.00196		-0.00845		-0.00169		-0.00767**	
External	-0.0626***		-0.0225		-0.00120		-0.00750		-0.000630		-0.00338	
Wage Index	6.288***		3.076***									
MSA:												
Dallas/Fort Worth	0.196***		0.151***		-0.00652*		-0.00436		0.00175*		0.00243	
Houston	-0.166***		-0.0626**		-0.0108**		-0.00469		0.00121		-0.00115	
Charlson Index:												
1 to 2	0.000808		0.0572***		0.00682**		0.0340***		-0.000463		-0.00783***	
3 to 4	0.0447		0.115***		0.0332***		0.0887***		-0.000310		-0.0134***	
5+	0.0813**		0.141***		0.0606***		0.135***		0.00190		-0.00373	
Male	0.0495***		0.0154		-0.00379		-0.00614		0.00150*		0.00238	
Transfer In	0.0231		-0.0378		0.0121		0.0144		0.00499		-0.00201	
Transfer Out	-0.266		0.0813		0.154***		0.326***		-0.00190		-0.00762	
Age:												
26 to 35	0.0277		-0.00817		-0.00239		0.00200		0.000444		0.00146	

36 to 45	0.0121	-0.0236	-0.00434	0.00406	0.000789	0.00568*
46 to 55	0.0172	-0.0527**	0.000485	0.00764	0.000950	0.00672**
56 to 64	0.00442	-0.105***	-0.00257	0.00269	0.000660	0.00946***
Length of Stay:						
1	0.0864	-0.209*	0.0112	0.0261		
2 to 5	0.542***	0.228**	0.0273*	0.0410		
6 to 9	1.118***	0.785***	0.0690***	0.0634*		
10+	2.041***	1.662***	0.136***	0.145***		
Outpatient	-0.737***	-0.928***	-0.0161	0.0102		
NISS:						
2 to 3	0.0600***		-0.00563		-0.00306***	
4	0.140***		0.00180		-0.00278**	
5 to 8	0.211***		-0.00740*		-0.00208*	
12 to 15		0.0515**		-0.00670		-0.00386
16 to 24		0.239***		-0.00368		0.00280
25+		0.578***		0.0127		0.0183***
Year:						
2011	-0.147***	-0.0821*	0.000279	-0.00508	-0.00191	0.00726
2012	-0.191***	-0.0476	-0.00118	0.00937	-0.00152	0.00457
2013	-0.149***	-0.0352	-0.00545	0.00587	-0.00163	0.00495
2014	-0.0894**	-0.0538	-0.00438	-0.0180	-0.00207	0.00624
2015	-0.0425	-0.00701	-0.00107	0.00817	-0.000245	-0.000570
2016	0.0512	0.0921**	0.00435	0.00233	-0.001948	0.00257
2017	0.0321	0.0766*	0.000114	0.000143	-0.00179	0.00237
2018	0.0381	0.0344	-0.00146	0.00703	-0.00180	-0.00257
2019						
Constant	3.36***	6.92***	0.0258	-0.0201486	0.00342*	0.0026989
N	19,334	14,251	19,334	14,251	19,334	14,251

*** p<0.001, ** p<0.01, * p<0.05

All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Transfer In/Out, Age groups, and MSA.

Spending and readmission regressions also include Length of Stay groups and Outpatient.

Spending regressions also include Wage Index.

NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 9: Effect of Trauma Verification on Outcomes by Severity Score and Year with Length of Stay <=1 day, 2011-2019

	Spending		Readmissions		Mortality	
	All NISS		All NISS		All NISS	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Pre-upgrade	-0.280***		0.00406*		-0.00300	
Upgraded	0.104*		0.00421		0.00209	
Interactions with year:		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*		*Upgraded + Upgraded * 201X:*
Upgraded * 2016	-0.534***	-0.430***	-0.00973	-0.00552	-0.00052	0.00157
Upgraded * 2017	-0.335***	-0.231***	-0.00143	0.00278	-0.00390	-0.00180
Upgraded * 2018	-0.274***	-0.170***	-0.00332	0.000884	0.00359	0.00568
Upgraded * 2019		0.104*		0.00421		0.00209
Injury Body Region:						
Head/neck	0.136***		-0.00250		-0.000238	
Chest	0.216***		-0.00108		0.000726	
Abdominal & pelvic content	0.0778**		-0.000896		0.00126	
Extremities & pelvic girdle	0.123***		-0.00487**		-0.00829***	
Face	0.0730**		-0.00412		-0.00903***	
External	0.0217		-0.00194		-0.00589***	
Wage Index	11.1***					
MSA:						
Dallas/Fort Worth	0.262***		-0.00166		0.00255	
Houston	-0.129***		-0.00323		0.00596**	
Charlson Index:						
1 to 2	-0.0212		0.00407**		-0.00482**	
3 to 4	0.00672		0.0120***		-0.00602*	
5+	0.0526		0.0119***		-0.00156	
Male	0.0574***		-0.000370		0.00276*	
Transfer In	-0.0855		-0.00349		-0.00532	
Transfer Out	-0.234		0.278***		-0.0108	
Age:						
26 to 35	0.0104		-0.000302		0.00166	
36 to 45	-0.0111		-0.00136		0.00377*	
46 to 55	0.0113		-0.000363		0.00421*	
56 to 64	-0.0207		0.00193		0.00313	
Outpatient	-0.854***		-0.0238***			
NISS 9+	0.213***		-0.0000607		0.0226***	
Year:						
2011	-0.0745**		-0.00458		0.00484	
2012	-0.116***		-0.00107		0.000327	
2013	-0.161***		-0.00316		0.00107	
2014	-0.0490		-0.00207		0.00275	
2015	0.0325		-0.00502		0.00109	
2016	0.167***		0.00249		0.00105	
2017	0.121***		-0.000798		0.00291	
2018	0.0680*		-0.000135		-0.00250	
2019						
Constant	-1.25*		0.0282***		0.00229	
N	16,847		16,847		16,847	

*** p<0.001, ** p<0.01, * p<0.05

All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Transfer In/Out, Age groups, and MSA.

Spending and readmission regressions also include Outpatient.

Spending regressions also include Wage Index.

NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 10: Effect of Trauma Verification on Outcomes by Severity Score and Hospital with Length of Stay <=1 day, 2011-2019

	Spending		Readmissions		Mortality	
	All NISS		All NISS		All NISS	
	Regression	Marginal Effects	Regression	Marginal Effects	Regression	Marginal Effects
Upgraded Trauma Centers:		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*		*Hospital + (Hospital * Upgraded):*
Hospital A	-0.142	-0.0060469	0.000288	-0.00795	-0.00173	-0.000324
Hospital A* Upgraded	0.136		-0.00824		0.00141	
Hospital B	-0.141**	-0.289*	-0.00197	0.0405**	-0.00587	-0.00745
Hospital B* Upgraded	-0.149		0.0425**		-0.00158	
Hospital C	-0.0677	0.275***	0.00116	-0.00829	0.000711	0.0112
Hospital C* Upgraded	0.343***		-0.00945		0.0105	
Hospital D	-0.228*	0.131*	0.0259**	-0.00932	0.00168	0.00282
Hospital D* Upgraded	0.359**		-0.0352**		0.00115	
Hospital E	-0.559***	-0.0718	-0.0212	0.0346**	-0.00959	0.0367***
Hospital E* Upgraded	0.487**		0.0557***		0.0463**	
Hospital F	-0.608***	-0.396***	0.00341	-0.00770	-0.00100	0.00138
Hospital F* Upgraded	0.212*		-0.0111		0.00239	
Hospital G	0.0836	0.252***	0.0128*	-0.00969	-0.00769	-0.00574
Hospital G* Upgraded	0.168		-0.0225*		0.00195	
Hospital H	-0.363***	-0.0887	0.0109*	0.0130*	-0.00526	0.00333
Hospital H* Upgraded	0.276**		0.00215		0.00858	
Hospital I	-0.760***	-0.377***	0.00182	0.00518*	-0.00757**	0.000381
Hospital I* Upgraded	0.383**		0.00336		0.00795	
Injury Body Region:						
Head/neck	0.145***		-0.00256		-0.000295	
Chest	0.224***		-0.000830		0.000687	
Abdominal & pelvic content	0.0838***		-0.000957		0.00105	
Extremities & pelvic girdle	0.121***		-0.00493**		-0.00823***	
Face	0.0682**		-0.00414		-0.00895***	
External	0.0345*		-0.00208		-0.00601***	
Wage Index	11.56***					
MSA:						
Dallas/Fort Worth	0.302***		-0.00232		0.00328*	
Houston	-0.118***		-0.00466		0.00669**	
Charlson Index:						
1 to 2	-0.0175		0.00410**		-0.00485**	
3 to 4	0.00912		0.0118***		-0.00616*	
5+	0.0525		0.0120**		-0.00145	
Male	0.0567***		-0.000313		0.00275*	
Transfer In	-0.0546		-0.00388		-0.00509	
Transfer Out	-0.267*		0.279***		-0.010198	
Age:						
26 to 35	0.00230		-0.000438		0.00171	
36 to 45	-0.0161		-0.00153		0.00362*	
46 to 55	0.00271		-0.000412		0.00421*	
56 to 64	-0.0285		0.00176		0.00315	
Outpatient	-0.860***		-0.0235***			
NISS 9+	0.208***		-0.000224		0.0224***	
Year:						
2012	-0.0401		0.00320		-0.00475	
2013	-0.0814**		0.000909		-0.00387	
2014	0.0148		0.00157		-0.00154	
2015	0.104***		-0.000774		-0.00395	
2016	0.214***		0.00595*		-0.00389	
2017	0.144***		0.00385		-0.00291	
2018	0.0870**		0.00480		-0.00692*	
2019	0.102**		0.00530		-0.00546	
Constant	-1.789**		0.0245***		0.00687*	
N	16,847		16,847		16,847	

*** p<0.001, ** p<0.01, * p<0.05

All regressions include year fixed effects, NISS groups, Injury Body Region, Charlson Index groups, Gender, Transfer In/Out, Age groups, and MSA.
Spending and readmission regressions also include Outpatient.
Spending regressions also include Wage Index.
NISS= New Injury Severity Score; MSA= Metropolitan Statistical Area

Appendix Table 11: Patients Treated at a Level I or II Trauma Center in Houston, Austin, and Dallas-Fort Worth MSAs by Availability of Level I or II Trauma Centers in their residence's Hospital Service Area (HSA)

			Does the HSA where the patient resides contain one or more Level I or II trauma centers?				
			No		Yes		Total
			Count	%	Count	%	
Was the patient treated at a Level I or II trauma center?	No	Count	7,656	44%	9,657	56%	17,313
		%	45%		28%		
	Yes	Count	9,336	27%	25,364	73%	34,700
		%	55%		72%		
	Total		16,992		35,021		52,013