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Outcomes by time-to-OR for penetrating abdominal trauma patients

Braylee Grisel, BS [a], Alexander Gordee, MS [b], Maragatha Kuchibhatla, Ph.D. [b], Zachary Ginsberg, MD [a], Suresh Agarwal, MD [a], Krista Haines, DO, MA [a,*]

[a] Division of Trauma and Acute Care Surgery, Department of Surgery, Duke University Medical Center, Durham, NC, USA
[b] Department of Biostatistics, Duke University School of Medicine, Durham, NC, USA

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ABSTRACT

Introduction: Time-To-OR is a critical process measure for trauma performance. However, this measure has not consistently demonstrated improvement in outcome.
Study design: Using TQIP, we identified facilities by 75th percentile time-to-OR to categorize slow, average, and fast hospitals. Using a GEE model, we calculated odds of mortality for all penetrating abdominal trauma patients, firearm injuries only, and patients with major complication by facility speed. We additionally estimated odds of mortality at the patient level.
Results: Odds of mortality for patients at slow facilities was 1.095; 95% CI: 0.746, 1.608; $p = 0.64$ compared to average. Fast facility OR = 0.941; 95% CI: 0.780, 1.133; $p = 0.52$. At the patient-level each additional minute of time-to-OR was associated with 1.5% decreased odds of in-hospital mortality (OR 0.985; 95% CI:0.981, 0.989; $p < 0.001$). For firearm-only patients, facility speed was not associated with odds of in-hospital mortality (p-value = 0.61). Person-level time-to-OR was associated with 1.8% decreased odds of in-hospital mortality (OR 0.982; 95% CI: 0.977, 0.987; $p < 0.001$) with each additional minute of time-to-OR. Similarly, failure-to-rescue analysis showed no difference in in-hospital mortality at the patient level ($p = 0.62$) and 0.4% decreased odds of in-hospital mortality with each additional minute of time-to-OR at the patient level (OR 0.996; 95% CI: 0.993, 0.999; $p = 0.004$).
Conclusion: Despite the use of time-to-OR as a metric of trauma performance, there is little evidence for improvement in mortality or complication rate with improved time-to-OR at the facility or patient level. Performance metrics for trauma should be developed that more appropriately approximate patient outcome.

1. Introduction

Time-to-OR is a critical process measure for hospital trauma performance. During the COVID19 Pandemic, hospital capacity issues have jumped to the forefront of public health discourse [1]. At the same time, the United States has continued to experience a twin epidemic of rising gun violence [2]. Previous measures used to evaluate trauma performance include time-to-OR and failure to rescue rates. Previous studies show mixed results regarding time to OR and associated mortality differences [3-8], and we hypothesized that some of the lack of improved mortality could be attributed to differential complication rates for fast and slow facilities.

In the 1970s, Dr. Cowley of Baltimore's Shock Trauma Center coined the phrase “golden hour” to describe the principle of timely care for trauma victims [9], a phrase which has maintained a prominence in the trauma literature ever since [6,7,9]. While one hour has not always proven to be the perfect barometer for quality trauma care, prompt treatment of penetrating injuries does have a significant effect on mortality outcomes, an effect that varies based on location of the wound, mechanism of injury and injury severity scale [3-8,10-12]. Much of this previous research focuses specifically on prehospital time [4,6-9,12,13]. While interventions in prehospital transportation have reduced time to hospital, there have been mixed results regarding any associated mortality benefit. However, time-to-OR continues to be used as a ubiquitous measure of trauma center performance and quality throughout the United States.

The aim of this study was to demonstrate whether faster time-to-OR is associated with improved mortality for trauma patients both at the facility and patient level and whether these outcomes are affected by

* Corresponding author at: Division of Trauma, Critical Care, and Acute Care Surgery, Duke University Medical Center, DUMC 2837, Durham, NC 27710, USA.
E-mail addresses: braylee.grisel@duke.edu (B. Grisel), alexander.gordee@duke.edu (A. Gordee), maragatha.kuchibhatla@duke.edu (M. Kuchibhatla), Zachary.ginsberg@duke.edu (Z. Ginsberg), suresh.agarwal@duke.edu (S. Agarwal), krista.haines@duke.edu (K. Haines)
Social media: .

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whether patients suffer from serious complication. Trauma performance metrics should ideally capture interventions that lead to significant improvement in patient care. Mortality and complication rate are measures that approximate outcomes important to patients and should correlate well with actual trauma performance. With the continued rise in firearm trauma in the United States, it is essential to develop performance metrics that truly impact and improve patient lives.

2. Methods

2.1. Data and cohort derivation

Data was obtained from the participant use files (PUFs) from the Trauma Quality Improvement Project (TQIP) National Trauma Data Bank (NTDB) for years 2010–2020. Additionally, facility identifiers were obtained from the American College of Surgeons (ACS) to link patients to specific facilities in a non-identifiable manner. These facility keys are consistent across years when applicable. We restricted our analyses to only patients reporting directly to a facility with an ACS verification level of I or II, aged 15 years or older with penetrating abdominal trauma treated surgically. Trauma type was identified by ICD-9 and ICD-10 External Cause Codes (*E*-codes), and injury location was determined using Abbreviated Injury Scale (AIS) codes starting with 5, which indicates an injury to the abdominal region. Surgical treatment was determined by the occurrence of an abdominal ICD-9 or ICD-10 Procedure Coding System (PCS) within 360 min of ED admission.

Patients were excluded if they had an AIS code starting with 1, 3, or 4 – indicating injuries to the head, neck, or thorax respectively – and an injury severity score of at least 3. Patients with an AIS code starting with 5 (abdomen) and a severity score of 6 (fatal) were also excluded. Patients were additionally excluded if they died in the emergency department (ED) or if they had unknown time-to-procedure. Patients were excluded at the facility-level on a year-by-year basis if the facility had less than four otherwise qualifying patients in a year, or if the facility-specific 75th percentile of time-to-procedure among all qualifying cases that year was <5 min, as this scenario was deemed likely to be data reporting errors.

2.1.1. Statistical methods

Facilities were classified on a year-by-year basis based on their time from ED arrival to abdominal procedure (time-to-OR). Funnel plots were used to identify outliers in terms of their time-to-OR. As in Thomas et al. (2021), the 75th percentile of time-to-OR was used to assess facility performance instead of median time-to-OR [3]. For each year, upper and lower control limits were calculated as described in Kuhrij et al. (2021) using the proportion method [15]. Upper and lower control limits were calculated from the 95% confidence interval from the normal approximation to the binomial distribution to account for the number of observations from each facility, with facilities with fewer patients having wider intervals. Facilities with a proportion of times exceeding the overall 75th percentile that fell below the lower control limit were classified as fast facilities, while those facilities with a proportion of times exceeding the overall 75th percentile that was above the upper control limit were classified as slow facilities. If the proportion of times exceeding the overall 75th percentile was between the two control limits, the facility was considered average speed.

Patient demographics, clinical characteristics, and outcomes were summarized using mean with standard deviation (SD), median with interquartile range (IQR), or frequency with percentage as appropriate and reported by facility speed classification. Association between variables and facility speed classification were assessed using Kruskal-Wallis tests for continuous measures and Chi-square tests for categorical measures. The same tables were additionally generated for the subset of patients with firearm injuries, and again for the subset of patients with major hospital complications.

A generalized estimating equation (GEE) with a logistic link function (Logistic GEE) was used to model the odds of in-hospital mortality among patients with penetrating abdominal trauma. An exchangeable correlation structure was assumed at the facility-level and confidence intervals for the estimates were calculated using the empirical standard errors. The model adjusted for facility-level characteristics (ACS level I/II, hospital type, teaching status, bed size, and yearly number of penetrating abdominal trauma injuries meeting inclusion criteria treated in the year of patient's injury) and patient-level characteristics (age, sex, race/ethnicity, firearm injury, ISS, systolic blood pressure (SBP) and pulse rate at ED presentation, year of injury). A small subset of patients were missing one or both of ED SBP or ED pulse rate. Mean-value imputation and an indicator variable for missingness were included for these measures. Equivalent sub-analyses were performed on the sub-groups of patients with firearm injuries and major hospital complications respectively. Patients missing sex and hospital outcome were excluded from all analyses. All analyses were performed using SAS software version 9.4 (SAS Institute, Cary, NC) and R version 3.4.3 (R Foundation for Statistical Computing, Vienne, Austria). Statistical significance was defined as $p < 0.05$, without accounting for multiple testing.

3. Results

Our cohort included 41,534 patients. Fast facilities had an average door-to-OR time of 41.0±37 (mean+/− SD) minutes as compared to 99.4 +/− 66.8 min for slow facilities, with a median time-to OR of 32, 48, and 83 min for fast, average, and slow respectively (Table 3). After adjusting for all other covariates included in the model, the speed classification of a facility was not associated with the odds of in-hospital mortality (overall p-value = 0.74) (Table 4). Person-level time-to-OR, however, was associated with a decrease in the odds of in-hospital mortality, with each additional minute of time-to-OR (from ED arrival) being associated with a 1.5% decrease in the odds of in-hospital mortality (OR 0.985; 95% CI: 0.981, 0.989; $p < 0.001$). Patients with a firearm injury experienced a 137.9% increase in the odds of in-hospital mortality when compared to patients without a firearm injury (OR 2.379; 95% CI: 2.033, 2.784; p < 0.001).

Patient age and sex was similar across hospitals of varying speeds (Table 1). White patients presented more often to slow facilities (44.1%) vs fast facilities (30.1%). Conversely, Black patients presented more often to fast facilities (48.6%) vs slow facilities (34.6%). Hispanic patients were more likely to present to slow facilities (30.2%) vs fast facilities (20.8%). Patients of other races were similar across hospital speeds. Sex was similar across all facilities. Fast hospitals had the lowest proportion of Medicaid and Medicare patients (29.3% vs 33.4% at slow) and the highest rate of self-pay patients (33.6% vs 27.9% at slow). Patients with private/commercial insurance were similar across hospital speeds.

Patients seen at faster facilities more frequently presented with firearm injuries (47.8% vs 58.0% vs 65.1% for slow/average/fast hospitals, respectively; $p < 0.001$) (Table 2). A slight majority (52.3%) of patients at slow facilities presented with stabbing-type injuries as opposed to firearm injuries. The number and severity of injuries, as determined by the AIS score, was slightly higher at faster facilities. The mean number of abdominal injuries was 2.3, 2.4, and 2.5 (standard deviation (SD) 1.5, 1.6, 1.6; $p < 0.001$) at slow/average/fast hospitals respectively, and the sum of abdominal AIS scores was 5.1, 5.7, and 6.0 (SD 4.4, 4.7, 4.9; p < 0.001) respectively. These value differences were not likely to be clinically significant between average and fast facilities.

The patients seen at slow facilities had slightly lower ISS in comparison to average and fast facilities, with mean ISS of 9.3, 10.3, and 10.6 (SD 7.0, 7.4, and 7.4; p < 0.001) respectively (Table 3). Patients had a longer length of stay in faster facilities, with median length-of-stay in hours of 125.5, 136.7, and 144.7 for slow, average, and fast hospitals respectively. Patient discharge disposition differed across facility speed,

Table 1
Patient Demographics for All Penetrating Abdominal Trauma Patients. The demographics of included patients are presented in Table 1 by facility speed.

	1. Slow ($N = 1231$)	2. Average ($N = 34,452$)	3. Fast ($N = 5851$)	Total ($N = 41,534$)	p value
Age (years)					0.4255[1]
Missing	0	0	0	0	
Mean (SD)	32.9 (12.9)	33.4 (13.1)	33.2 (12.9)	33.3 (13.1)	
Median	30.0	30.0	30.0	30.0	
Q1, Q3	23.0, 40.0	23.0, 41.0	23.0, 41.0	23.0, 41.0	
Range	(15.0–88.0)	(15.0–89.0)	(15.0–89.0)	(15.0–89.0)	
Sex					0.1259[2]
Missing	0	7	0	7	
Male	1087 (88.3%)	30,029 (87.2%)	5149 (88.0%)	36,265 (87.3%)	
Female	144 (11.7%)	4416 (12.8%)	702 (12.0%)	5262 (12.7%)	
Race					<0.0001[2]
White	543 (44.1%)	12,278 (35.6%)	1763 (30.1%)	14,584 (35.1%)	
Black	426 (34.6%)	15,231 (44.2%)	2846 (48.6%)	18,503 (44.5%)	
Other	262 (21.3%)	6943 (20.2%)	1242 (21.2%)	8447 (20.3%)	
Ethnicity					<0.0001[2]
Missing	99	2894	658	3651	
Hispanic or Latino	342 (30.2%)	6946 (22.0%)	1080 (20.8%)	8368 (22.1%)	
Not Hispanic or Latino	790 (69.8%)	24,612 (78.0%)	4113 (79.2%)	29,515 (77.9%)	
Primary payment method					<0.0001[2]
Missing	30	1578	684	2292	
Medicaid	401 (33.4%)	11,317 (34.4%)	1515 (29.3%)	13,233 (33.7%)	
Not Billed (for any reason)	14 (1.2%)	257 (0.8%)	85 (1.6%)	356 (0.9%)	
Self-Pay	335 (27.9%)	9868 (30.0%)	1736 (33.6%)	11,939 (30.4%)	
Private/Commercial Insurance	239 (19.9%)	6712 (20.4%)	968 (18.7%)	7919 (20.2%)	
Medicare	69 (5.7%)	1844 (5.6%)	260 (5.0%)	2173 (5.5%)	
Other Government	95 (7.9%)	1695 (5.2%)	268 (5.2%)	2058 (5.2%)	
Other	48 (4.0%)	1181 (3.6%)	335 (6.5%)	1564 (4.0%)	

[1] Kruskal Wallis.
[2] Chi-Square.

Table 2
Injury characteristics. The characteristics of the injuries sustained by included patients are presented in Table 2 by facility speed.

	1. Slow ($N = 1231$)	2. Average ($N = 34,452$)	3. Fast ($N = 5851$)	Total ($N = 41,534$)	p value
Firearm injury					<0.0001
No	643 (52.2%)	14,453 (42.0%)	2040 (34.9%)	17,136 (41.3%)	
Yes	588 (47.8%)	19,999 (58.0%)	3811 (65.1%)	24,398 (58.7%)	
Cut/pierce injury					<0.0001
No	587 (47.7%)	20,011 (58.1%)	3813 (65.2%)	24,411 (58.8%)	
Yes	644 (52.3%)	14,441 (41.9%)	2038 (34.8%)	17,123 (41.2%)	
Number of abdominal AIS scores					<0.0001
Missing	0	0	0	0	
Mean (SD)	2.3 (1.5)	2.4 (1.6)	2.5 (1.6)	2.4 (1.6)	
Median	2.0	2.0	2.0	2.0	
Q1, Q3	1.0, 3.0	1.0, 3.0	1.0, 3.0	1.0, 3.0	
Range	(1.0–10.0)	(1.0–19.0)	(1.0–13.0)	(1.0–19.0)	
Number of not-unknown abdominal AIS scores					<0.0001
Missing	0	0	0	0	
Mean (SD)	2.3 (1.5)	2.4 (1.5)	2.5 (1.6)	2.4 (1.6)	
Median	2.0	2.0	2.0	2.0	
Q1, Q3	1.0, 3.0	1.0, 3.0	1.0, 3.0	1.0, 3.0	
Range	(1.0–10.0)	(1.0–19.0)	(1.0–13.0)	(1.0–19.0)	
Minimum abdominal AIS severity					<0.0001
Missing	0	0	0	0	
Mean (SD)	1.7 (0.8)	1.8 (0.8)	1.9 (0.8)	1.8 (0.8)	
Median	2.0	2.0	2.0	2.0	
Q1, Q3	1.0, 2.0	1.0, 2.0	1.0, 2.0	1.0, 2.0	
Range	(1.0–5.0)	(1.0–5.0)	(1.0–5.0)	(1.0–5.0)	
Maximum abdominal AIS severity					<0.0001
Missing	0	0	0	0	
Mean (SD)	2.4 (1.0)	2.6 (1.1)	2.6 (1.0)	2.6 (1.1)	
Median	2.0	3.0	3.0	3.0	
Q1, Q3	2.0, 3.0	2.0, 3.0	2.0, 3.0	2.0, 3.0	
Range	(1.0–5.0)	(1.0–5.0)	(1.0–5.0)	(1.0–5.0)	
Sum of known abdominal AIS severities					<0.0001
Missing	0	0	0	0	
Mean (SD)	5.1 (4.4)	5.7 (4.7)	6.0 (4.9)	5.7 (4.7)	

Table 3
Outcomes by Facility Speed (full cohort). The outcomes of all included patients are summarized in Table 4, presented by facility speed.

	1. Slow (N = 1231)	2. Average (N = 34,452)	3. Fast (N = 5851)	Total (N = 41,534)	p value
Time from ED arrival to OR (minutes)					<0.0001
Missing	0	0	0	0	
Mean (SD)	99.4 (66.8)	66.3 (55.6)	41.0 (37.0)	63.7 (54.8)	
Median	83.0	48.0	32.0	46.0	
Q1, Q3	49.0, 128.0	32.0, 79.0	23.0, 48.0	31.0, 75.0	
Range	(0.0–360.0)	(0.0–360.0)	(0.0–357.0)	(0.0–360.0)	
ICU LOS (days)					<0.0001
Missing	816	18,401	2983	22,200	
Mean (SD)	4.9 (7.2)	5.6 (8.0)	6.0 (8.0)	5.7 (8.0)	
Median	3.0	3.0	3.0	3.0	
Q1, Q3	2.0, 5.0	2.0, 6.0	2.0, 6.0	2.0, 6.0	
Range	(1.0–85.0)	(1.0–174.0)	(1.0–83.0)	(1.0–174.0)	
Time on ventilator (days)					0.1384
Missing	982	24,489	3987	29,458	
Mean (SD)	3.8 (5.0)	4.3 (7.0)	4.5 (8.6)	4.4 (7.3)	
Median	2.0	2.0	2.0	2.0	
Q1, Q3	1.0, 4.0	1.0, 4.0	1.0, 4.0	1.0, 4.0	
Range	(1.0–42.0)	(1.0–114.0)	(1.0–224.0)	(1.0–224.0)	
Time to ED discharge (hours)					<0.0001
Missing	25	1766	380	2171	
Mean (SD)	1.4 (2.5)	1.4 (5.9)	1.0 (3.0)	1.3 (5.5)	
Median	0.9	0.5	0.4	0.5	
Q1, Q3	0.5, 1.6	0.3, 1.2	0.2, 0.7	0.3, 1.1	
Range	(0.0–25.1)	(0.0–456.4)	(0.0–88.3)	(0.0–456.4)	
ED discharge disposition					<0.0001
Missing	4	78	20	102	
Floor bed (general admission, non-specialty unit bed)	38 (3.1%)	976 (2.8%)	79 (1.4%)	1093 (2.6%)	
Observation unit (unit that provides <24 hour stays)	2 (0.2%)	82 (0.2%)	13 (0.2%)	97 (0.2%)	
Telemetry/step-down unit (less acuity than ICU)	2 (0.2%)	167 (0.5%)	57 (1.0%)	226 (0.5%)	
Operating Room	1161 (94.6%)	32,301 (94.0%)	5572 (95.6%)	39,034 (94.2%)	
Intensive Care Unit (ICU)	24 (2.0%)	848 (2.5%)	110 (1.9%)	982 (2.4%)	
Time from ED arrival to hospital discharge (hours)					<0.0001
Missing	8	206	52	266	
Mean (SD)	188.9 (255.3)	210.7 (274.1)	228.5 (285.3)	212.5 (275.2)	
Median	125.5	136.7	144.7	137.4	
Q1, Q3	68.5, 208.0	78.7, 233.8	87.2, 257.5	80.2, 235.2	
Range	(0.8–3262.6)	(0.1–5916.8)	(0.1–3936.0)	(0.1–5916.8)	
Time from ED arrival to hospital discharge (days)					<0.0001
Missing	2	202	67	271	
Mean (SD)	7.4 (9.9)	8.6 (11.1)	9.5 (11.8)	8.7 (11.2)	
Median	5.0	6.0	6.0	6.0	
Q1, Q3	2.0, 8.0	3.0, 10.0	4.0, 11.0	3.0, 10.0	
Range	(1.0–137.0)	(1.0–248.0)	(1.0–164.0)	(1.0–248.0)	
Hospital discharge disposition					<0.0001
Discharged/Transferred to a short-term general hospital for inpatient care	42 (3.4%)	655 (1.9%)	68 (1.2%)	765 (1.8%)	
Discharged/Transferred to an Intermediate Care Facility (ICF)	0 (0.0%)	142 (0.4%)	24 (0.4%)	166 (0.4%)	
Discharged/Transferred to home under care of organized home health service	81 (6.6%)	2637 (7.7%)	347 (5.9%)	3065 (7.4%)	
Left against medical advice or discontinued care	16 (1.3%)	604 (1.8%)	100 (1.7%)	720 (1.7%)	
Deceased/Expired	36 (2.9%)	1618 (4.7%)	306 (5.2%)	1960 (4.7%)	
Discharged to home or self-care (routine discharge)	906 (73.6%)	24,267 (70.4%)	4331 (74.0%)	29,504 (71.0%)	
Discharged/Transferred to Skilled Nursing Facility (SNF)	20 (1.6%)	536 (1.6%)	78 (1.3%)	634 (1.5%)	
Discharged/Transferred to hospice care	0 (0.0%)	22 (0.1%)	5 (0.1%)	27 (0.1%)	
Discharged/Transferred to court/law enforcement	22 (1.8%)	801 (2.3%)	135 (2.3%)	958 (2.3%)	
Discharged/Transferred to inpatient rehab or designated unit	53 (4.3%)	1586 (4.6%)	239 (4.1%)	1878 (4.5%)	
Discharged/Transferred to Long Term Care Hospital (LTCH)	3 (0.2%)	113 (0.3%)	23 (0.4%)	139 (0.3%)	
Discharged/Transferred to a psychiatric hospital or psychiatric distinct part unit of a hospital	36 (2.9%)	1248 (3.6%)	175 (3.0%)	1459 (3.5%)	
Discharged/Transferred to another type of institution not defined elsewhere	16 (1.3%)	223 (0.6%)	20 (0.3%)	259 (0.6%)	
Major complication					0.1467
No	1171 (95.1%)	32,361 (93.9%)	5480 (93.7%)	39,012 (93.9%)	
Yes	60 (4.9%)	2091 (6.1%)	371 (6.3%)	2522 (6.1%)	
In-hospital mortality					0.0022
Survived to discharge	1195 (97.1%)	32,834 (95.3%)	5545 (94.8%)	39,574 (95.3%)	
In-hospital mortality	36 (2.9%)	1618 (4.7%)	306 (5.2%)	1960 (4.7%)	

Table 4
Primary Analysis Results of Predictors* of In-Hospital Mortality.

	Odds Ratio (95% Confidence Interval)	p-value
Time-to-OR		
Facility Speed Rank		
Average (Reference)	–	–
Slow	1.095 (0.746, 1.608)	0.643
Fast	0.941 (0.780, 1.133)	0.520
Time-to-OR (Minutes)	0.985 (0.981, 0.989)	<0.001
Demographics		
Age (years)	1.028 (1.023, 1.033)	<0.001
Female sex (ref = Male)	0.801 (0.667, 0.962)	0.017
Race/Ethnicity		
Non-Hispanic White (Reference)	–	–
Non-Hispanic Black	1.036 (0.906, 1.184)	0.606
Non-Hispanic other race	1.601 (1.292, 1.984)	<0.001
Hispanic of any race	0.938 (0.786, 1.119)	0.476
Clinical Characteristics		
Firearm Injury (ref = No)	2.379 (2.033, 2.784)	<0.001
ISS	1.113 (1.104, 1.121)	<0.001

* Additionally adjusted for ACS Verification level, hospital teaching status, hospital bed size, year of injury, hospital-specific number of penetrating abdominal injuries treated surgically in the year of injury, ED SBP, and ED pulse rate.

with slow facilities having the highest proportion of patients discharged to short-term general hospitals for inpatient care (3.4% vs 1.9% and 1.2% for average and fast facilities respectively). Average speed facilities had the highest proportion of patients discharged home under organized home health service (7.7% vs 6.6% and 5.9% for slow and fast facilities respectively), but the lowest proportion of patients with a routine discharge (70.4% vs 73.6% and 74.0% for slow and fast facilities respectively). Patients at slow facilities survived to discharge more frequently than at average and fast facilities (2.9% vs 4.7% and 5.2% respectively).

A lower proportion of slow facilities were ACS Level I when compared to average and fast facilities (44.4% vs 55.3% and 59.8% respectively). Hospital type (profit/non-profit) and teaching status were similar across hospital speeds. The mean number of yearly penetrating abdominal trauma patients seen was higher at fast facilities in comparison to slow and average facilities (21.2 vs 17.1 and 17.2; SD 22.9, 12.8, and 14.2 respectively), however the median number of penetrating abdominal trauma patients was lower at fast facilities (9 vs 13 and 13 respectively). In summary, it appears slow and average speed facilities saw a more consistent number of penetrating abdominal trauma patients per year, while fast facilities saw a highly variable number of patients per year, either slightly lower or much higher when compared to slow or average facilities.

3.1. Results for firearm injuries sub-analysis

This sub-analysis consisted only of those patients who had a firearm injury, with or without additional abdominal injuries.

After adjusting for all other covariates included in the model, the speed classification of a facility was not associated with the odds of in-hospital mortality (overall p-value = 0.61) (Table 5). The person-level time-to-OR however was again associated with a decrease in the odds of in-hospital mortality, with each additional minute of time-to-OR (from ED arrival) being associated with a 1.8% decrease in the odds of in-hospital mortality (OR 0.982; 95% CI: 0.977, 0.987; $p < 0.001$).

3.2. Results for failure-to-rescue sub-analysis

This sub-analysis consisted only of those patients who had a major complication in the hospital. Mortality in these patients is referred to as failure-to-rescue. A major complication was defined as one or more of the following: sepsis, pneumonia, ventilator-associated pneumonia, pulmonary embolism, acute respiratory distress syndrome, acute renal failure, cardiac arrest, myocardial infarction, or cerebrovascular accident. On full cohort analysis, there was no significant difference in major complication rate by hospital speed ($p = 0.15$) (Table 3).

Table 5
Predictors of Mortality in Firearm Injuries Sub-Group. The odds-ratios with 95% confidence intervals and p-values for the GEE model analyzing firearm injuries only are reported in Table 5.

	Odds Ratio (95% Confidence Interval)	p-value
Time-to-OR		
Facility Speed Rank		
Average (Reference)		
Slow	1.172 (0.780, 1.759)	0.445
Fast	0.931 (0.757, 1.145)	0.498
Time-to-OR (Minutes)	0.982 (0.977, 0.987)	<0.001
Facility Characteristics		
ACS Verification Level		
Level I Trauma Center (Reference)	–	–
Level II Trauma Center	1.283 (1.022, 1.610)	0.032
Hospital Type		
Non-Profit (Reference)	–	–
For-Profit	0.925 (0.706, 1.211)	0.57
Government	0.472 (0.361, 0.617)	<0.001
Teaching Status		
University (Reference)	–	–
Nonteaching	1.101 (0.793, 1.527)	0.565
Community	1.041 (0.854, 1.268)	0.691
Bed Size		
>600 (Reference)	–	–
401–600	0.972 (0.824, 1.147)	0.736
201–400	0.829 (0.662, 1.038)	0.103
≤ 200	1.312 (0.880, 1.958)	0.183
Number of yearly penetrating abdominal trauma cases	0.992 (0.987, 0.997)	0.003
Demographics		
Age (years)	1.025 (1.019, 1.030)	<0.001
Female sex (ref = Male)	0.812 (0.674, 0.98)	0.03
Race/Ethnicity		
Non-Hispanic White (Reference)	–	–
Non-Hispanic Black	1.062 (0.916, 1.230)	0.426
Non-Hispanic other race	1.625 (1.280, 2.065)	<0.001
Hispanic of any race	0.972 (0.801, 1.179)	0.772

After adjusting for all other covariates included in the model, the speed classification of a facility was not associated with the odds of in-hospital mortality (overall p-value = 0.62) (Table 6). The person-level time-to-OR was associated with a decrease in the odds of in-hospital mortality, with each additional minute of time-to-OR (from ED arrival) being associated with a 0.4% decrease in the odds of in-hospital mortality (OR 0.996; 95% CI: 0.993, 0.999; $p = 0.004$).

4. Discussion

Improving hospital trauma performance is essential as gun violence continues to be a major source of mortality across the United States. As far as we are aware, this is the first study associating time-to-OR with failure to rescue rates for abdominal trauma patients in American hospitals. Our study continued to demonstrate a lack of mortality benefit among fast hospitals, and, surprisingly, showed decreased odds of mortality with increasing door-to-OR time on patient level analysis. We additionally showed that failure to rescue rates did not differ between facilities with slow or fast OR times. This study will hopefully propel new insights and areas of research on these important performance metrics. Likely due to variation in standard of care for different types of abdominal trauma, time-to-OR demonstrated little predictive ability in both complication rate and mortality. Future metrics developed to evaluate trauma center performance should focus on interventions that better correlate to outcomes that truly improve patient lives.

Table 6
Predictors of Mortality in Failure-to-Rescue Sub-Group. The odds-ratios with 95% confidence intervals and p-values for this GEE model of only patients who suffered major complication are reported in Table 6.

	Odds Ratio (95% Confidence Interval)	p-value
Time-to-OR		
Facility Speed Rank		
Average (Reference)	–	–
Slow	0.769 (0.437, 1.353)	0.362
Fast	1.015 (0.772, 1.335)	0.915
Time-to-OR (Minutes)	0.996 (0.993, 0.999)	0.004
Facility Characteristics		
ACS Verification Level		
Level I Trauma Center (Reference)	–	–
Level II Trauma Center	1.258 (0.887, 1.783)	0.197
Hospital Type		
Non-Profit (Reference)	–	–
For-Profit	1.074 (0.759, 1.519)	0.687
Government	0.640 (0.108, 3.773)	0.622
Teaching Status		
University (Reference)	–	–
Nonteaching	1.117 (0.658, 1.897)	0.681
Community	1.202 (0.898, 1.610)	0.216
Bed Size		
>600 (Reference)	–	–
401–600	0.911 (0.690, 1.202)	0.510
201–400	0.792 (0.556, 1.128)	0.196
≤ 200	1.374 (0.951, 1.987)	0.091
Number of yearly penetrating abdominal trauma cases	0.998 (0.991, 1.005)	0.515
Demographics		
Age (years)	1.010 (1.003, 1.017)	0.007
Female sex (ref = Male)	1.166 (0.868, 1.567)	0.307
Race/Ethnicity		
Non-Hispanic White (Reference)	–	–
Non-Hispanic Black	1.046 (0.818, 1.337)	0.722
Non-Hispanic other race	1.467 (0.957, 2.249)	0.079
Hispanic of any race	1.090 (0.773, 1.537)	0.624

Our study reinforces previous literature showing lack of improved mortality at the facility level for faster door-to-OR performance, while failing to show that this is attributable to failure to rescue after complication. These differences are maintained after controlling for demographic factors (age, race, ethnicity, insurance status), injury severity (ED vitals, AIS, ISS) as well as other factors that could impact abdominal trauma performance (number of abdominal trauma cases per year, firearm injury vs other penetrating trauma). Most surprisingly, we found decreased odds of mortality with increasing time-to-OR at the patient level. These results persisted in analysis on all penetrating abdominal trauma patients, as well as in sub analysis of firearm injuries only and sub analysis of solely patients suffering major complication. This analysis is limited due to the limited number of variables available in the TQIP database and the heterogeneity of fast facilities. However, our study demonstrates that more research is needed into whether time-to-OR is truly a strong and accurate metric for hospital trauma performance.

While all traumatic injuries require prompt medical intervention, penetrating abdominal injuries show the greatest potential for mortality impact with decreased time to operation. Gunshot wounds to the head and chest tend to be the most fatal even with standard of care treatment, limiting potential for improving time to OR in a multiple victim or disaster situation [4,16-18]. Conversely, extremity wounds are highly survivable even with a longer time to surgery if hemostasis is achieved. Abdominal wounds, however, are often highly fatal within several hours, with stronger evidence for improved outcomes with faster door-to-OR time. In a study by Clark et al., the probability of death for abdominal trauma patients increased by 0.35% per minute up to ninety minutes spent in the emergency department prior to laparotomy [5]. However, our study demonstrated little impact on patient outcome with a high sample size. It is likely that even abdominal trauma is too heterogeneous for fast time-to-OR to be a useful universal standard. While time-to-laparotomy is often used as a measure of surgeon performance, variation in abdominal injury pattern may mean that longer time to OR is standard of care for some injuries vs others. For example, a bowel injury may have less urgency than an aortic tear, leaving more time for ideal operative planning including CT scanning. Differences in injury pattern are likely to have influenced our results, despite similar ISS and AIS among fast and slow facilities.

Failure to rescue is another commonly used process measure for trauma performance. This measures the ability of hospitals to successfully treat surgical complications such as pneumonia, pulmonary embolism (PE), or cardiac injury after they occur [19]. This measure is performed by analyzing mortality only on the subpopulation of patients with major complication. Recent research has shown that over-resuscitation is associated with increased complication rates in trauma [20,21] due to impacts on hypocalcemia and coagulopathy. We hypothesized that patients who went to the OR more quickly were also likely to have higher rates of over-resuscitation and more complications after treatment. However, complication rate was similar across all hospital types and failure-to-rescue was not impacted by time-to-OR at the facility or patient level.

Relatively little attention has been paid in the literature to delays in treatment for trauma patients that occur after arrival to the hospital, as opposed to prehospital time [3,5,7]. Staffing is one factor that could impact hospital performance when treating time sensitive injuries. When resuscitation teams are led by an in house, experienced trauma surgeon, time to OR decreases from 66 to 50 min for penetrating trauma patients [22,23], however this did not impact overall mortality. Thomas et al. created a model to evaluate variation in hospital level performance on time to OR for penetrating abdominal injuries. The slowest hospitals in this study showed a 75th percentile time to OR of 83 min compared with 35 min at the fastest hospitals [3], again without a significant difference in mortality. Experienced trauma surgeons make clinical decisions based on more factors than can be captured in the TQIP database, such as clinical experience and gestalt, that may impact time-to-OR. An experienced clinician may decide that a patient is stable enough to wait for the OR based on criteria outside of what was controlled for in the database and this could explain some of the unexpected mortality improvement for longer door-to-OR. The TQIP database does not provide information on staffing and team member makeup, so we were unable to evaluate how this may impact time-to-OR and failure to rescue.

An important aspect of our study to acknowledge is the demographic differences among patients treated at fast and slow hospitals. While hospitals did not show a difference in injury type or severity, they did show a difference in race, sex and insurance status of patients. We would expect that mortality should be improved by faster door-to-OR time, but instead we see no difference with a significant opposite effect at the patient level. One explanation could be the socioeconomic burden of hospitals who treat a higher number of penetrating trauma patients with faster time-to-OR. Fast hospitals in our sample had more black and uninsured patients, with a higher number of firearm injuries treated per year. Previous studies have shown increased failure-to-rescue rates among patients without insurance who undergo trauma laparotomy [24]. While fast hospitals may perform better on paper, there are likely differences in treatment options due to ability to pay and baseline comorbidities due to SES burden that are not captured by the TQIP dataset. It is also possible that these underserved hospitals have more difficulties with trauma surge conditions and patient volume, which may also be part of the reason why we fail to see improved mortality with faster door-to-OR performance. However, fast hospitals had lower rates of Medicaid patients suggesting that the SES burden may be lower than hypothesized.

There are many commonly used performance metrics for trauma care in the United States. Trauma patients are especially vulnerable, suffering from unexpected injury without pre-operative optimization. Trauma surgeons must make speedy and difficult decisions with little information, making this area of surgery an essential field for improvement of quality and performance metrics. A scoping review found that trauma performance metrics are especially variable, and none have especially strong evidence in clinical practice [25]. Trauma performance metrics are limited by the highly variable and volatile nature of traumatic injury – It is difficult to find measures that have a broad impact when each individual patient and injury is so clinically different from one another. However, there is a strong drive to improve this essential realm of clinical research. The American College of Surgeons publishes the Trauma Quality Improvement Program specifically for this purpose. While there is limited evidence that time-to-OR has a significant impact on morbidity and mortality, there is a large world to explore in other measures of trauma center performance. It is essential for surgeons to create trauma center metrics that truly make a difference in improving outcomes for patients suffering from the epidemic of gun violence in the United States.

4.1. Limitations

There are several limitations of our study design. TQIP is a retrospective database so it is difficult to infer any sort of causality for our findings. This database does not capture all comorbidities that can be found in our patients, and comorbid implications for demographic differences must be inferred. Additionally, this database does not track outcomes post discharge, limiting a full analysis of failure to rescue for complications that may have occurred after discharge related to trauma care. We were also unable to evaluate performance of time-to-OR based on trauma surge conditions which would have provided more information on how these results influence performance during mass casualty events. This data does not capture the nuances of team composition so we could also not evaluate whether there is difference in time-to-OR based on who is leading trauma activation or staffing level. Fast facilities showed a wider heterogeneity in number of abdominal cases per year, which could point to unmeasured differences in facility performance outside of time-to-OR. We did not perform an analysis of differences by specific intra-abdominal organ injury, which could have affected speed of time-to-OR. However, this is unlikely to have impacted the overall results because of the similarity in ISS and AIS across time-to-OR while also controlling for vital signs including hypotension. Additionally, our results were strengthened on analysis of only intra-abdominal firearm injuries, which are likely to have a similar standard of care regardless of specific organ affected. Overall, it is likely there are variables not captured in this dataset that may explain improved mortality for longer door-to-OR and more prospective research is needed to find the cause of these findings.

5. Conclusion

Despite the use of time-to-OR as a metric of trauma performance, there is little evidence for improvement in odds of mortality or death after major complications with improved time-to-OR at the facility or patient level. Future research can explore other process measures that may capture trauma center performance with a higher impact on patient outcome.

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CRediT authorship contribution statement

Braylee Grisel: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Alexander Gordee:** Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. **Maragatha Kuchibhatla:** Formal analysis, Investigation, Methodology, Supervision. **Zachary Ginsberg:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Suresh Agarwal:** Conceptualization, Investigation, Project administration, Supervision, Writing – review & editing. **Krista Haines:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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