Failure to rescue in trauma: Early and late mortality in low- and high-performing trauma centers

Naveen F. Sangji, MD, MPH, Laura Gerhardinger, MA, Bryant W. Oliphant, MD, MBA, Anne H. Cain-Nielsen, MS, John W. Scott, MD, MPH, *and* **Mark R. Hemmila, MD***, Ann Arbor, Michigan*

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BACKGROUND: Failure to rescue (FTR) is defined as mortality following a complication. Failure to rescue has come under scrutiny as a quality metric to compare trauma centers. In contrast to elective surgery, trauma has an early period of high expected mortality because of injury sequelae rather than a complication. Here, we report FTR in early and late mortality using an externally validated trauma patient database, hypothesizing that centers with higher risk-adjusted mortality rates have higher risk-adjusted FTR rates.

METHODS: The study included 114,220 patients at 34 Levels I and II trauma centers in a statewide quality collaborative (2016–2020) with Injury Severity Score of ≥5. Emergency department deaths were excluded. Multivariate regression models were used to produce center-level adjusted rates for mortality and major complications. Centers were ranked on adjusted mortality rate and divided into quintiles. Early deaths (within 48 hours of presentation) and late deaths (after 48 hours) were analyzed.

RESULTS: Overall, 6.7% of patients had a major complication and 3.1% died. There was no difference in the mean risk-adjusted complication rate among the centers. Failure to rescue was significantly different across the quintiles (13.8% at the very low-mortality centers vs. 23.4% at the very-high-mortality centers, $p < 0.001$). For early deaths, there was no difference in FTR rates among the highest and lowest mortality quintiles. For late deaths, there was a twofold increase in the FTR rate between the lowest and highest mortality centers (9.7% vs. 19.3%, $p < 0.001$), despite no difference in the rates of major complications (5.9% vs. 6.0%, $p = 0.42$).

CONCLUSION: Low-performing trauma centers have higher mortality rates and lower rates of rescue following major complications. These differences are most evident in patients who survive the first 48 hours after injury. A better understanding of the complications and their role in mortality after 48 hours is an area of interest for quality improvement efforts. (*J Trauma Acute Care Surg.* 2022;93: 176–186.

LEVEL OF EVIDENCE: Prognostic and Epidemiologic; Level III.
KEY WORDS: Failure to rescue; quality improvement; mortality; trauma center performance.

Failure to rescue (FTR) is defined as mortality following a complication.[1] The concept was first described in the elective surgery population; however, it has since been explored as a hospital quality metric for the trauma patient population.[2,3] In elective surgery cohorts, hospitals with either very high mortality or very low mortality had similar rates of overall complications, and hospital mortality has been shown to be associated with FTR.[4,5] For trauma patients, two multicenter studies have demonstrated that both complication and FTR rates are elevated in high-mortality centers.[3,6] However, a conflicting study produced findings comparable with what has been shown in elective surgery, with similar complication rates in high- and low-mortality centers, but higher rates of FTR in the high-mortality hospitals.[2] Recently, FTR has come under scrutiny as a quality metric, and its use as a patient safety indicator has been questioned.[7]

In contrast to elective surgery, trauma has an early period of high expected mortality because of injury sequelae rather than a complication (e.g., hemorrhage). The complications occurring in the elective surgery and trauma populations differ in that the complications happening in trauma patients are often related to their injury sequelae and burden rather than being solely due to their underlying comorbid conditions or the operation performed. For a proportion of trauma patients, there may have been no operation performed, and yet they are at a high risk for morbidity and mortality (e.g., traumatic brain injury). Given these differences, there has been interest in exploring FTR as a potential metric that impacts hospital-level mortality in trauma patients.

Our goal was to investigate the association of FTR with hospital-level mortality for trauma patients and to explore differences in mortality, complications, and FTR in the early and late phase of care after hospital admission. We hypothesized that centers with higher risk-adjusted mortality would have higher FTR rates, with no difference in risk-adjusted complication rates. We also postulate that trauma patients who survive the first 48 hours after injury are more likely to die after sustaining a complication, whereas those who die within 48 hours of presentation are more likely to die because of injury progression or factors other than a complication. To perform this study, we used a statewide, externally validated patient database that adheres to a common standard of data definitions and data collection as part of a collaborative quality initiative.[8] An improved understanding of the association of complications with mortality in relation to the phase of care for trauma patients may help identify potential processes and interventions that can reduce complications and costs.[9–11]

PATIENTS AND METHODS

Study Design and Setting

This is a retrospective cohort study of trauma patients treated at 34 American College of Surgeons Committee on Trauma–verified Level I or II trauma centers participating in the Michigan Trauma Quality Improvement Program (MTQIP). The MTQIP is a collaborative quality initiative that started in 2008, funded by the Blue Cross Blue Shield of Michigan, which uses enhanced trauma registry data collection.[9] In addition to standard trauma registry data, MTQIP collects additional information on outcomes and processes of care and uses a robust data validation program.[12] Currently, 10 Level I and 24 Level II trauma centers in the state of Michigan participate in the MTQIP.

Participants

Patients aged 16 years or older with an Injury Severity Score of ≥5 who presented with a blunt or penetrating mechanism of

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From the Department of Surgery (N.F.S, J.W.S., M.R.H.), Department of Orthopaedic Surgery (B.W.O.), and Center for Healthcare Outcomes and Policy (N.F.S., L.G., B.W.O., A.H.C.-N., J.W.S., M.R.H.), University of Michigan, Ann Arbor, Michigan.
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Address for reprints: Naveen F. Sangji, MD, MPH, Department of Surgery, University of Michigan, University Hospital 1C421, 1500 E Medical Center Dr, SPC 5033, Ann Arbor, MI 48109-5033; email: nsangji@med.umich.edu.

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TABLE 1. Baseline Patient Demographic, Injury Severity, and Clinical Characteristics of the Patients, According to Hospital Quintile of Mortality

Characteristic	Very Low Mortality (n = 18,968)	Low Mortality (n = 20,816)	Medium Mortality (n = 18,317)	High Mortality (n = 38,603)	Very High Mortality (n = 17,516)	*p*
Mean age, y	68.1	63.2	61.4	57.6	63.7	<0.001
Age, %						<0.001
16–25 y	5.6	7.7	9.9	11.8	7.3	
26–45 y	10.5	15.5	17.0	21.1	15.9	
46–65 y	21.0	23.6	23.7	25.0	22.7	
65–75 y	16.8	16.3	14.4	13.5	16.0	
>75 y	46.0	36.8	35.0	28.5	38.0	
Male, %	45.9	53.5	52.7	57.4	52.2	<0.001
Race, %						<0.001
White	88.6	87.4	86.9	73.8	83.3	
Black	7.3	9.5	9.8	20.6	14.7	
Other	4.2	3.1	3.3	5.5	1.9	
Mechanism, %						<0.001
Blunt	98.0	95.6	95.2	94.1	94.4	
Penetrating	2.0	4.4	4.8	5.9	5.6	
Injury Severity Score, %						<0.001
5–15	85.6	80.4	83.9	80.2	84.3	
15–24	8.6	12.1	9.9	12.6	9.8	
24–35	4.9	6.2	5.1	5.8	5.0	
>35	1.0	1.3	1.1	1.3	0.8	
AIS head/neck >2, %	16.8	21.0	17.0	20.6	18.7	<0.001
AIS face >2, %	0.3	0.5	0.4	0.4	0.3	0.001
AIS chest >2, %	14.0	18.1	15.7	17.4	13.9	<0.001
AIS abdomen >2, %	3.5	5.3	4.5	4.9	3.9	<0.001
AIS extremity >2, %	37.6	31.5	32.9	28.5	34.4	<0.001
AIS external >2, %	0.2	0.3	0.2	0.2	0.2	0.059
ED heart rate, %						<0.001
51–120 bpm	88.8	91.8	93.3	91.8	91.0	
>120 bpm	3.1	3.7	4.7	4.8	4.4	
0–50 bpm	0.8	1.0	0.8	0.8	0.8	
Missing	7.4	3.5	1.2	2.6	3.8	
ED systolic blood pressure, %						<0.001
>90 mm Hg	90.3	93.8	95.8	94.8	93.7	
61–90 mm Hg	1.4	1.9	2.2	2.1	2.1	
≤60 mm Hg	0.1	0.2	0.6	0.3	0.3	
Missing	8.2	4.0	1.3	2.8	3.9	
Glasgow Coma Scale motor, %						<0.001
1	1.5	2.8	2.5	2.7	1.9	
2–5	3.0	3.8	4.2	4.2	3.5	
6	81.9	80.8	85.9	86.2	87.1	
Missing	13.7	12.6	7.4	6.9	7.6	
Transfer in, %	8.2	26.2	15.8	19.8	12.4	<0.001
Intubated, %	4.2	6.6	6.6	6.0	4.5	<0.001
Comorbid diseases, %	0.0	0.0	0.0	0.0	0.0	
Active chemotherapy	0.8	0.8	0.5	0.5	0.6	<0.001
Advanced directive limiting care	7.8	5.2	6.7	4.6	5.1	<0.001
Alcohol use disorder	6.9	8.0	9.3	8.7	9.3	<0.001
Angina	0.5	0.6	1.1	0.6	0.5	<0.001
Bleeding risk	20.2	17.8	16.6	14.7	18.8	<0.001
Cerebrovascular accident	3.8	3.2	3.2	3.3	4.1	<0.001
Chronic obstructive pulmonary disease	8.1	11.0	9.2	9.2	7.7	<0.001
Chronic renal failure	1.5	1.5	1.5	1.3	1.8	<0.001

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TABLE 1. *(Continued)*

Characteristic	Very Low Mortality (n = 18,968)	Low Mortality (n = 20,816)	Medium Mortality (n = 18,317)	High Mortality (n = 38,603)	Very High Mortality (n = 17,516)	*p*
Congestive heart failure	6.4	6.2	4.7	6.0	6.9	<0.001
Current smoker	17.3	21.7	26.5	27.4	24.5	<0.001
Dementia	14.2	11.0	12.1	8.7	12.3	<0.001
Diabetes mellitus	17.3	16.5	15.5	14.3	16.8	<0.001
Disseminated cancer	0.8	0.7	0.5	0.6	0.7	0.022
Drug use disorder	7.2	13.2	15.6	19.7	14.8	<0.001
Functionally dependent health status	37.3	23.2	22.7	18.2	25.9	<0.001
History of myocardial infarction	0.7	0.5	0.6	0.5	0.2	<0.001
Hypertension requiring medication	53.3	46.3	43.5	39.6	49.1	<0.001
Liver disease	0.9	1.4	1.1	0.8	1.1	<0.001
Major psychiatric illness	20.8	25.3	25.6	22.5	21.5	<0.001
Obesity	1.0	0.9	1.2	3.9	7.4	<0.001
Peripheral vascular disease	2.1	2.1	2.7	2.3	2.0	<0.001
Steroid use	3.3	3.2	2.8	2.0	3.0	<0.001

Race was self-reported.
bpm, beats per minute.

injury to a Level I or Level II trauma center between January 2016 and June 2020 were included in the study. Patients were excluded if they had been entered into the database before the center enrolling in the MTQIP. Patients with burns were excluded. Patients with no signs of life at initial evaluation in the emergency department (ED) (systolic blood pressure, 0; pulse, 0; Glasgow Coma Scale score, 3) and those who died while in the ED were excluded to limit the impact of unsurvivable injury.[13]

Data Collection and Data Definitions

Data collection was performed using the existing trauma registry at participating hospitals with a modular add-on for MTQIP specific data. Michigan Trauma Quality Improvement Program publishes a data definitions dictionary, based upon the National Trauma Data Standard, which is available online and updated annually. Trauma registrars and data abstractors from participating centers undergo training in MTQIP and National Trauma Data Standard data definitions. Data are transmitted to the coordinating center at 2-month intervals. Each MTQIP center undergoes an annual externally conducted data validation audit.[8,12]

Major complications were defined as in-hospital complications identified as "serious" in MTQIP. The MTQIP identifies a complication event as "serious" based on association with increased mortality risk within the quality collaborative or substantial use of hospital resources.[9,10,12,14,15] The following complications were included as a "major complication" in the analysis: acute kidney injury, acute renal insufficiency, acute respiratory distress syndrome, *Clostridioides difficile* colitis, cardiac arrest with cardiopulmonary resuscitation, catheter-related bloodstream infection/central line-associated bloodstream infection, deep vein thrombosis, enterocutaneous fistula or gastrointestinal leak, extremity compartment syndrome, myocardial infarction (MI), pneumonia (including ventilator-associated pneumonia), pressure ulcer, pulmonary embolism, severe sepsis, stroke/cerebrovascular accident, unplanned admission to intensive care unit, unplanned intubation, unplanned visit to the operating room.

Failure to rescue was defined as in-hospital mortality after at least one major complication. Early deaths were defined as deaths within 48 hours of presentation to the ED or hospital. Late deaths were defined as deaths after 48 hours of presentation to the ED or hospital. The hospitals were separated into five groups or quintiles based on risk-adjusted mortality rates.

Outcomes

The two primary outcomes studied were the rate of major complications and death after a major complication (FTR) during the index hospitalization. The secondary outcomes studied were the rate of major complications and FTR for patients who died within 48 hours of presentation and for patients who died after 48 hours of presentation.

Analysis

To investigate the association between overall hospital mortality, the rate of major complications, and FTR, the hospitals were ranked very low, low, medium, high, and very high for mortality using standardized mortality rates. First, we assessed mortality at the hospital level using standard risk-adjustment methods.[5,16] Univariate differences in patient characteristics (such as age, sex, Injury Severity Score, preexisting comorbid conditions) and hospital characteristics (such as trauma center verification level) and outcomes by hospital outlier status were evaluated using χ^2 or Fisher's exact tests for categorical variables and analysis of variance *F* tests or Kruskal-Wallis tests for continuous variables.

Multivariable logistic regression models were used to account for differences in patient and trauma center characteristics, allowing for risk adjustment at the patient level. Patient characteristics that were nonconstantly related to the outcome through all values of the variable (e.g., a 1-year increase in age has a different impact for younger vs. older patients) were entered into the models as categorical instead of continuous covariates. A category of missing was included for the variables ED heart rate, ED systolic blood pressure, and Glasgow Coma Score motor. Models were created using forward stepwise logistic regression.

TABLE 2. Incidence of Major Complications Among FTR Patients, According to Hospital Quintile of Mortality

Incidence of Complication Among Overall FTR Patients, %	All Centers (n = 1,379)	Very Low Mortality (n = 153)	Low Mortality (n = 254)	Medium Mortality (n = 225)	High Mortality (n = 488)	Very High Mortality (n = 259)	*p*
Acute kidney injury	11.4	10.5	12.2	11.6	12.3	9.3	0.76
Acute renal insufficiency	2.1	1.3	2.8	3.6	1.2	2.3	0.27
Acute respiratory distress syndrome	6.5	4.6	3.5	7.1	9.0	5.4	0.04
C. diff colitis	2.4	1.3	2.4	1.3	3.3	2.3	0.48
Cardiac arrest with cardiopulmonary resuscitation	46.2	47.7	42.1	45.3	48.4	45.9	0.59
Catheter-related bloodstream infection/central line-associated bloodstream infection	0.4	0.7	0.4	0.0	0.4	0.4	0.88
Deep vein thrombosis	4.4	2.0	5.9	6.7	4.1	3.1	0.12
Enterocutaneous fistula or gastrointestinal leak	0.1	0.0	0.4	0.0	0.0	0.4	0.50
Extremity compartment syndrome	0.1	0.0	0.0	0.4	0.0	0.4	0.44
Myocardial infarction	7.2	5.9	8.7	9.3	5.9	6.9	0.42
Pneumonia (including VAP)	23.5	21.6	29.5	24.0	21.7	21.6	0.14
Pressure ulcer	5.1	5.9	6.7	5.3	4.5	4.2	0.69
Pulmonary embolism	2.2	2.6	2.4	1.3	2.7	1.5	0.74
Severe sepsis	9.6	11.8	10.6	9.3	10.0	6.6	0.40
Stroke/cerebrovascular accident	5.1	4.6	3.9	5.3	5.3	5.8	0.89
Unplanned admission to ICU	26.6	24.2	22.4	27.1	28.5	28.2	0.41
Unplanned Intubation	35.2	38.6	32.7	34.7	35.9	35.1	0.81
Unplanned visit to the operating room	2.7	3.9	2.0	2.2	2.7	3.1	0.78
Incidence of Complication Among Early (Within 48 h) FTR Patients, %	**All Centers (n = 334)**	**Very Low Mortality (n = 33)**	**Low Mortality (n = 64)**	**Medium Mortality (n = 52)**	**High Mortality (n = 125)**	**Very High Mortality (n = 60)**	***p***
Acute Kidney Injury	3.0	0.0	4.7	0.0	5.6	0.0	0.09
Acute renal insufficiency	0.3	0.0	0.0	0.0	0.8	0.0	0.79
Acute respiratory distress syndrome	1.8	0.0	0.0	1.9	3.2	1.7	0.53
C. diff colitis	0.0	0.0	0.0	0.0	0.0	0.0	.
Cardiac arrest with cardiopulmonary resuscitation	89.5	81.8	90.6	86.5	89.6	95.0	0.33
Catheter-related bloodstream infection/central line-associated bloodstream infection	0.0	0.0	0.0	0.0	0.0	0.0	.
Deep vein thrombosis	0.3	0.0	0.0	1.9	0.0	0.0	0.25
Enterocutaneous fistula or gastrointestinal leak	0.0	0.0	0.0	0.0	0.0	0.0	.
Extremity compartment syndrome	0.0	0.0	0.0	0.0	0.0	0.0	.
Myocardial infarction	3.3	0.0	3.1	5.8	4.0	1.7	0.59
Pneumonia (including VAP)	0.6	0.0	1.6	0.0	0.0	1.7	0.49
Pressure ulcer	0.0	0.0	0.0	0.0	0.0	0.0	.
Pulmonary embolism	0.3	0.0	1.6	0.0	0.0	0.0	0.38
Severe sepsis	0.9	0.0	3.1	0.0	0.8	0.0	0.30
Stroke/cerebrovascular accident	1.5	0.0	0.0	1.9	2.4	1.7	0.69
Unplanned admission to ICU	7.8	18.2	4.7	7.7	5.6	10.0	0.13
Unplanned intubation	12.9	15.2	9.4	17.3	12.0	13.3	0.76
Unplanned visit to the operating room	2.1	6.1	0.0	3.8	0.8	3.3	0.19
Incidence of Complication Among Late (After 48 h) FTR Patients, %	**All Centers (n = 1,015)**	**Very Low Mortality (n = 117)**	**Low Mortality (n = 189)**	**Medium Mortality (n = 169)**	**High Mortality (n = 341)**	**Very High Mortality (n = 199)**	***p***
Acute kidney injury	14.4	13.7	14.8	15.4	15.2	12.1	0.86
Acute renal insufficiency	2.7	1.7	3.7	4.7	1.2	3.0	0.13
Acute respiratory distress syndrome	8.2	6.0	4.8	8.9	11.4	6.5	0.05
C. diff colitis	3.3	1.7	3.2	1.8	4.7	3.0	0.36
Cardiac arrest with cardiopulmonary resuscitation	31.1	36.8	25.4	32.0	32.0	31.2	0.31
Catheter-related bloodstream infection/central line-associated bloodstream infection	0.5	0.9	0.5	0.0	0.6	0.5	0.88

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TABLE 2. *(Continued)*

Incidence of Complication Among Late (After 48 h) FTR Patients, %	All Centers (n = 1,015)	Very Low Mortality (n = 117)	Low Mortality (n = 189)	Medium Mortality (n = 169)	High Mortality (n = 341)	Very High Mortality (n = 199)	*p*
Deep vein thrombosis	5.8	2.6	7.9	8.3	5.6	4.0	0.14
Enterocutaneous fistula or gastrointestinal leak	0.2	0.0	0.5	0.0	0.0	0.5	0.52
Extremity compartment syndrome	0.2	0.0	0.0	0.6	0.0	0.5	0.47
Myocardial infarction	8.7	7.7	10.6	10.7	7.0	8.5	0.56
Pneumonia (including VAP)	31.7	28.2	39.2	32.0	31.1	27.6	0.13
Pressure ulcer	7.0	7.7	9.0	7.1	6.5	5.5	0.72
Pulmonary embolism	2.9	3.4	2.6	1.8	3.8	2.0	0.64
Severe sepsis	12.7	15.4	13.2	12.4	14.1	8.5	0.34
Stroke/cerebrovascular accident	6.2	6.0	5.3	6.5	6.2	7.0	0.97
Unplanned admission to ICU	33.4	26.5	28.6	33.1	38.4	33.7	0.079
Unplanned intubation	43.3	46.2	40.7	40.8	46.0	41.7	0.63
Unplanned visit to the operating room	3.0	3.4	2.6	1.8	3.5	3.0	0.85

C. diff, *Clostridioides difficile*; ICU, intensive care unit; VAP, ventilator-associated pneumonia.

Adjusted odds ratios were reported for logistic regression models. We adjusted for within-hospital clustering by using robust standard errors. The final model included 27 covariates with a *c* statistic of 0.91 (Supplemental Digital Content, Supplementary Table 1, http://links.lww.com/TA/C499).

Predicted probabilities of death from these models were used to estimate expected rates of deaths for each center. The ratio of observed-to-expected mortality was multiplied by the overall rate of death in the cohort to get the risk-adjusted rate of death for each center. Centers were then ranked according to risk-adjusted mortality and grouped into quintiles. The groups each included seven centers, except for the middle group which consisted of 6 hospitals.

Second, the same method identified previously was used to calculate risk-adjusted major complication rates and risk-adjusted mortality rates in patients who experienced a major complication.

Third, the entire process was repeated for early deaths (using only major complications within the first 48 hours of arrival to the ED) and late deaths. We used the same quintile groupings for each outcome, to compare center performance for each measure.

As a sensitivity analysis, we repeated the process by ranking the centers based on early versus late risk-adjusted mortality and calculating major complication rates and rate of death after a major complication. A second sensitivity analysis was conducted by repeating the main analysis with inclusion of patients who died in the ED in the study cohort.

Average values were expressed as mean ± SD. All statistical tests were two-sided. Statistical significance was defined as a p value of <0.05. Statistical analyses were performed using Stata 15.1 (StataCorp., College Station, TX).

This study was submitted to the University of Michigan Medical School Institutional Review Board and given a determination of "not regulated" status as secondary use of existing data from a quality assurance and quality improvement clinical activity. Secondary use of MTQIP data have been approved by the Michigan Medicine institutional review board under application HUM00041947. We followed the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines in this retrospective, cross-sectional study using observational data from the MTQIP (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/C500).

RESULTS

Of 235,888 patients in the MTQIP database, there were 115,729 patients within the time frame for the study. After excluding patients with no signs of life on arrival (n = 876) and those who died in the ED (n = 633), 114,220 patients met the inclusion and exclusion criteria. Centers were categorized into very low (seven centers), low (seven centers), medium (six centers), high (seven centers) ,and very high (seven centers) mortality groups, using the center level risk-adjusted mortality rates (Table 1). The baseline demographic and clinical characteristics of the patients stratified according to hospital mortality quintiles are included in Table 1. Patients at higher-mortality hospitals were more likely to be non-White, with higher rates of penetrating trauma, higher rates of smoking, and higher rates of obesity. Given the large sample size, comparisons across groups will virtually always result in p values <0.05 even when there may not be clinically relevant differences among the groups. The prevalence of major complications was 6.7% (n = 7,700). The observed rates of each complication in the entire FTR group across the quintiles of mortality are shown in Table 2. In addition, the complication rates are broken out for the early death (within 48 hours) and late death cohorts. The observed rates of each complication for all patients in the study across the quintiles of mortality are available in Supplemental Digital Content (Supplementary Table 2, http://links.lww.com/TA/C499).

The overall observed mortality rate was 3.1% (n = 3,570). Of these, 39% of patients (n = 1,383) died within the first 48 hours after presentation to the ED or hospital, and 61% (n = 2,187) died after 48 hours. The mortality rate among trauma patients without complications was 2.1% and, after at least one major complication, was 17.9%. Of all deaths, 39% were preceded by a major complication. The mean risk-adjusted mortality varied widely across the hospital quintiles, from 2.3% in the hospitals with very low mortality (lowest quintile) to 4.1% in the hospitals with very high mortality (highest quintile), $p < 0.001$ (Table 3). Hospitals with very high mortality or very low mortality had similar rates

TABLE 3. Trauma Center Outcomes, According to Hospital Quintile of Mortality

	Very Low Mortality (n = 18,968)	Low Mortality (n = 20,816)	Medium Mortality (n = 18,317)	High Mortality (n = 38,603)	Very High Mortality (n = 17,516)	*p*
No. centers	7	7	6	7	7	
No. Level 1 centers	1	3	1	4	1	
No. patients	17,962	19,119	17,082	35,901	16,456	
Outcome: all mortality						
Mean observed mortality	2.0	3.1	3.0	3.3	3.7	0.002
Mean expected mortality	2.7	3.6	3.1	3.1	2.8	0.156
Mean risk-adjusted mortality	2.3	2.7	3.0	3.4	4.1	<0.001
Mean observed major complication rate	5.4	8.0	6.7	7.2	5.6	0.107
Mean expected major complication rate	6.0	7.1	6.5	7.0	6.1	0.229
Mean risk-adjusted major complication rate	6.0	7.4	7.0	6.9	6.2	0.362
Patients who experienced a major complication						
No. patients	1,006	1,697	1,235	2,702	1,060	
Mean observed mortality	14.2	16.4	15.9	17.8	23.4	<0.001
Mean expected mortality	18.2	18.6	17.4	17.0	17.6	0.284
Mean risk-adjusted mortality (FTR)	14.0	15.8	16.4	18.6	23.7	<0.001
Outcome: death in first 48 h						
Mean observed mortality	0.9	1.2	1.2	1.5	1.1	0.110
Mean expected mortality	0.9	1.4	1.3	1.3	1.0	0.144
Mean risk-adjusted mortality	1.2	1.1	1.1	1.4	1.3	0.283
Mean observed major complication rate <48 h	2.4	3.1	2.9	2.8	2.4	0.521
Mean expected major complication rate <48 h	2.5	2.8	2.7	2.7	2.5	0.250
Mean risk-adjusted major complication rate <48 h	2.5	3.0	2.9	2.7	2.6	0.803
Patients who experienced a major complication <48 h						
No. patients	408	659	531	1021	454	
Mean observed mortality	8.2	9.8	8.0	13.4	11.6	0.341
Mean expected mortality	8.9	10.6	10.4	11.8	10.9	0.545
Mean risk-adjusted mortality (FTR)	10.4	9.9	8.1	11.8	11.4	0.577
Outcome: death after 48 h						
Mean observed mortality	1.1	1.9	1.9	1.9	2.6	<0.001
Mean expected mortality	1.8	2.2	1.8	1.8	1.7	0.125
Mean risk-adjusted mortality	1.1	1.6	1.9	2.0	2.8	<0.001
Mean observed major complication rate	5.2	7.7	6.5	6.9	5.4	0.099
Mean expected major complication rate	5.8	6.9	6.3	6.7	5.8	0.225
Mean risk-adjusted major complication rate	5.8	7.1	6.8	6.7	6.0	0.371
Patients who experienced a major complication						
No. patients	970	1,629	1,187	2,550	1,000	
Mean observed mortality	10.7	12.3	12.8	12.7	19.5	<0.001
Mean expected mortality	15.0	14.4	13.3	12.6	13.8	0.091
Mean risk-adjusted mortality (FTR)	9.8	11.7	13.6	13.7	19.4	<0.001

of risk adjusted major complications (6.2% and 6.1%, respectively, Fig. 1*A*). The rate of risk-adjusted major complication did not vary significantly across hospital mortality quintiles (Fig. 1*A*). However, the overall FTR rate in patients with a major complication was almost twice as high in hospitals in the very high mortality quintile as it was in those hospitals in the very low mortality quintile (23.4% vs. 13.8%, $p < 0.001$).

For patients who died in the first 48 hours, the risk-adjusted rate of mortality, major complications, and FTR did not vary significantly across hospital mortality quintiles (Fig. 1*B*). After excluding patients who died within the first 48 hours, patients treated at the very high-mortality hospitals had two-and-a-half times the likelihood of dying than patients treated at the very-low-mortality hospitals (2.8% vs. 1.1%, $p < 0.001$, Table 3) and two times the likelihood of dying after the development of at least one major complication (9.7% vs. 19.3%, $p < 0.001$, Fig. 1*C*), despite no significant differences in the likelihood of sustaining a major complication (5.9% vs. 6.0%, $p = 0.4$).

The mean expected mortality rates across the quintiles were not significantly different for the overall group, early death group, or late death group (Table 3). This suggests that the probability of death across the quintiles is the same; hence, observed differences in case mix across the quintiles did not contribute to differences in mortality. The risk-adjusted mortality differences were related to observed differences in mortality and not differences in the characteristics of the patients.

As a sensitivity analysis, we reorganized our mortality quintiles by ranking the centers based on risk-adjusted mortality

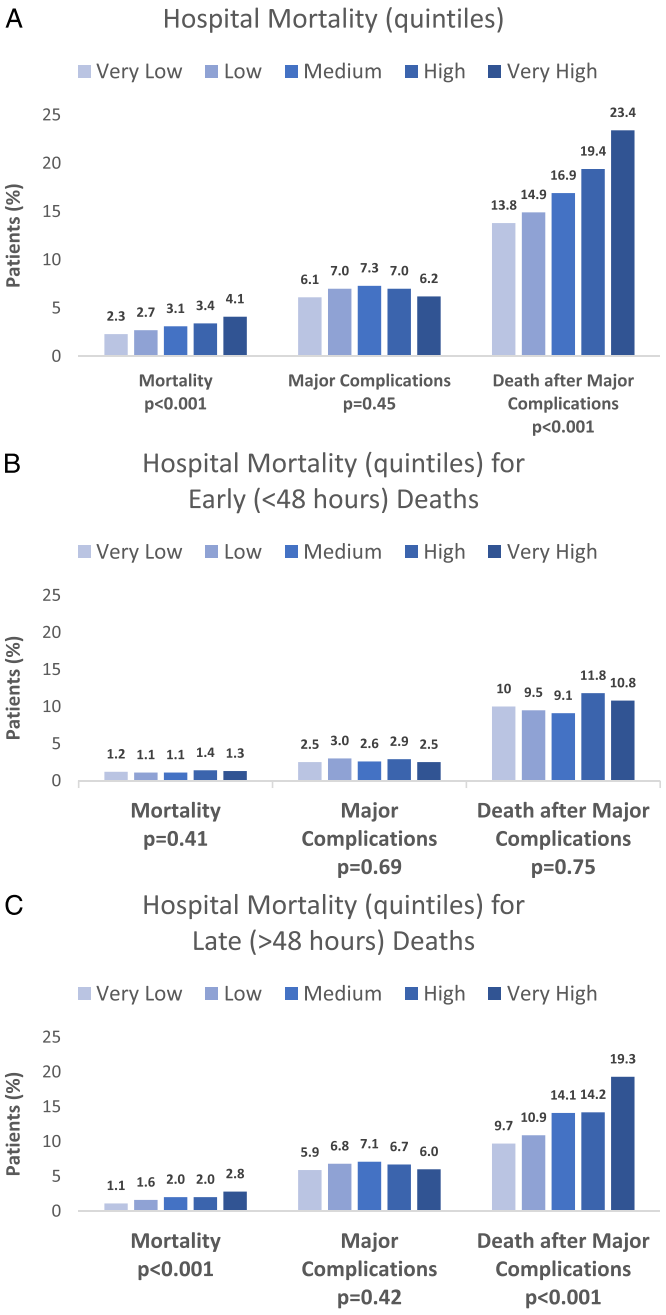

Figure 1. Rates of death, major complications, and death after major complications, according to hospital quintile of mortality, for (*A*) all deaths, (*B*) early deaths, and (*C*) late deaths. *Major complications include the following: acute kidney injury, acute renal insufficiency, acute respiratory distress syndrome, *Clostridioides difficile* colitis, cardiac arrest with cardiopulmonary resuscitation, catheter-related bloodstream infection/central line-associated bloodstream infection, deep vein thrombosis, enterocutaneous fistula or gastrointestinal leak, extremity compartment syndrome, myocardial infarction, pressure ulcer, pulmonary embolism, severe sepsis, stroke/cerebrovascular accident, unplanned admission to intensive care unit, unplanned intubation, unplanned visit to the operating room, and ventilator-associated pneumonia.

after 48 hours. Patients treated at the very-high-mortality hospitals in these reorganized quintiles still had two times higher FTR rate after the development of at least one major complication (9.5% vs. 19.3%, $p < 0.001$; Supplemental Digital Content, Supplementary Table 3, http://links.lww.com/TA/C499). Once again, there was no significant difference in the likelihood of sustaining a major complication (6.2% vs. 6.0%, $p = 0.6$). In an additional sensitivity analysis, we repeated the main analysis but included all patients who died in the ED in the cohort. Patients treated at the very-high-mortality hospitals in this analysis still had a two times higher FTR rate after the development of at least one major complication (9.0% vs. 18.5%, $p < 0.001$). Again, there was no significant difference in the likelihood of sustaining a major complication (5.9% vs. 5.7%, $p = 0.2$; Supplemental Digital Content, Supplementary Fig. 1, http://links.lww.com/TA/C501).

Treatments and interventions in trauma patients according to hospital mortality quintiles are shown in Table 4. Although patients in the lowest mortality hospitals underwent operations at a higher rate than those in the highest mortality hospitals (50.1% vs. 47.3%, $p < 0.001$), overall, there were no generalizable linear trends for rate of interventions such as angiography or surgical procedures and mortality.

DISCUSSION

Our study shows that variation in trauma center mortality rates is associated with FTR for patients with traumatic injury but not associated with differences in complication rates at these centers across quintiles. This mirrors what has been reported for the elective surgery patient population.[4,5] In our study, in-hospital mortality among trauma patients with at least one major complication was almost twofold greater in the very-high-mortality hospitals compared with the very-low-mortality hospitals. This difference was most evident in the patients who died with a complication >48 hours after admission. The FTR rate was similar across quintiles in the <48 hours cohort.

Previous studies in trauma patients have shown inconsistent results regarding complication rates. At least two studies have reported higher rates of both complications and FTR in hospitals with overall higher mortality.[3,6] Another study using the National Trauma Data Bank reported lower FTR rates in lower mortality centers, despite similar rates of complications in the low- and high-mortality hospitals, consistent with prior reports for elective surgery.[2] Our study reveals that, despite no significant differences in complication rates across low- and high-mortality hospitals, trauma patients at lower-mortality hospitals tend to less likely die after a major complication than patients at higher-mortality hospitals. This difference occurs primarily in patients who die >48 hours after admission.

An important difference between our study and prior studies assessing in-hospital mortality after at least one major complication in trauma patients is the use of an externally validated, robust, clinically rich data registry with confirmed data accuracy that improves the validity of analytic findings.[12] Previous registry-based studies for trauma patients have reported a much lower rate of complications in patients who died. For example, calculating the reported complications for patients who died in the study published by Glance et al.[2] revealed reporting of a major complication in 22% of patients who died. The study by Haas

TABLE 4. Treatments and Interventions of Trauma Patients, According to Hospital Quintile of Mortality

Incidence of Treatments and Interventions	Very Low Mortality (n = 18,968)	Low Mortality (n = 20,816)	Medium Mortality (n = 18,317)	High Mortality (n = 38,603)	Very High Mortality (n = 17,516)	*p*
Operation*	50.1	47.1	46.9	43.8	47.3	<0.001
Emergency operation**	5.8	15.2	12.7	12.1	7.2	<0.001
Intubated	4.2	6.6	6.6	6.0	4.5	<0.001
Neurosurgical intervention for TBI	7.7	8.9	9.7	7.4	8.4	<0.001
Surgery for hemorrhage control:						
Laparotomy	0.6	0.9	1.3	1.2	0.9	<0.001
Thoracotomy	<0.1	0.1	0.2	0.2	0.2	<0.001
Sternotomy	<0.1	<0.1	0.0	<1	<0.1	0.003
Extremity	0.1	0.2	0.3	0.3	0.2	<0.001
Neck	<0.1	0.1	<0.1	0.1	<0.1	0.36
Mangled extremity/traumatic amputation	<0.1	0.1	0.1	0.1	<0.1	0.007
Extraperitoneal pelvic packing	0.0	0.0	0.0	0.0	0.0	
Other skin/soft tissue	0.2	0.1	0.2	0.2	0.0	<0.001
Angiography						<0.001
Angiogram only	1.7	0.4	0.7	4.1	0.6	
Angiogram with embolization	3.2	1.1	1.1	7.1	0.9	
Angiogram with stenting	0.3	<1	0.0	0.7	0.0	
Angiogram with embolization and stent graft	0.1	<0.1	<0.1	0.3	<0.1	

*Operation: Surgical procedure performed after arrival to the trauma center, before death or discharge.
**Emergency operation: reported as "emergent" by surgeon or anesthesiologist after arrival to the trauma center; presence of an "E" after the ASA class indicates an emergent operation.
ASA, American Society of Anesthesiologists; TBI, traumatic brain injury.

et al.[3] reported a major complication in 20% of patients who died. Two studies using the Pennsylvania trauma registry reported complications in 12.4% and 16.9% of patients who died.[17,18] In contrast, our study captured at least one major complication in 39% of the patients who eventually died during their hospitalization. An analysis using the nationwide trauma registry in Japan captured complications for approximately 35% of trauma patients who died.[6] The Japanese study had two important differences compared with our study: first, their study cohort excluded patients who died within 48 hours of presentation; and second, they included all complications captured in the registry in their analysis, whereas we limited our analysis to major complications that are associated with increased mortality risk or resource utilization within our quality collaborative.

The lower rate of capture of complications from national registry studies was critiqued by Holena et al.,[19] who used chart abstractions to supplement the complications captured in a state registry for trauma patients at their institution and confirmed a significantly higher rate of complications among patients who died in their study. The complication rates in those who died reported by Holena et al.[19] (55–58%) are higher than those in our study, likely because their list of complications included several complications that have low associated mortality in MTQIP and hence were not included as a major complication in our study, for example, urinary tract infection and wound infection. Subsequently, the group proposed a new metric for FTR in trauma known as FTR-Trauma (FTR-T); however, the FTR-T metric relies on a complex calculation that estimates potential missed adverse events (complications) in patients who die.[20] The FTR-T has not been widely adopted as a potential quality metric in trauma, and does not resolve the underlying issue of missed capture of complications in trauma registries and databases.

The lower rate of complications reported for trauma patients who died in the studies using the National Trauma Data Bank compared with our study suggests that this discrepancy stems from complications not being reliably captured in national registries, rather than an actual higher rate of major complications in trauma patients who die at Level I and Level II trauma centers in Michigan. Multiple reports support our conclusion that the reported lower rate of major complications in trauma patients who die compared with the rates in our study are due to limitations of capturing complications in national registries.[19,21] Hence, while FTR may be an important driver of variation in hospital quality, it should be used with caution as a metric to assess trauma center performance in the absence of externally validated registries.

We found that pneumonia (including ventilator-associated pneumonia) and unplanned intubation are some of the most frequent complications in our population of trauma patients. This is consistent with other reports in the literature. Of the complications described for patients undergoing elective operations and for trauma patients in the FTR literature, pulmonary complications including pneumonia, and the need for intubation and mechanical ventilation rank as most frequent.[3–6,19,22,23] Prompt diagnosis and treatment of pneumonias may be an important component of preventing death in trauma patients.

Trauma patients have distinct differences in their complication and mortality risk profile from elective surgery patients. In elective surgery, all of the patients have undergone an operation; for trauma patients, they may receive operative or nonoperative management of their injuries. Operations performed in trauma patients are emergent or urgent. While trauma patients and elective surgery patients may have similar demographic and comorbidity profiles, each trauma patient presents with a unique

constellation of injuries that can influence outcomes. Examples are unsalvageable injuries or injuries that have mortality associated with progression of injury, for example, a severe head injury that deteriorates and leads to clinical brain death or withdrawal of care.

To address confounding from the timing of death and complications, we evaluated FTR after excluding patients who died within the first 48 hours of injury. Our findings were similar to those in elective surgery and revealed that, among patients who died after 48 hours after sustaining at least one major complication, the highest mortality centers had twice the likelihood of death compared with the lowest mortality centers, despite no significant difference in the rate of major complications across the quintiles. For patients who died within 48 hours of presentation to the ED, there was no difference in mortality rates, complications, or FTR, indicating that early deaths among trauma patients are related to patients presenting with unsurvivable injury or from progression of injury, rather than due to complications, compared with patients who die at least 48 hours after presentation. This finding was confirmed on sensitivity analysis in which patients who died in the ED were included.

For patients who survive beyond the first 48 hours after injury, theoretically, the mortality outcomes should be similar after experiencing a major complication if care is equivalent at all hospitals. The finding that low-performing trauma centers have higher mortality rates, higher FTR rates, and similar rates of complications suggests that identification and treatment of complication may be an important driver of quality in trauma centers. While we observed U-shaped acuity profiles in several patient characteristics with the highest acuity being in the middle performing centers, this was accounted for in our risk-adjustment models, and hence, any differences in patient acuity should not impact these findings. A better understanding of the complications and their role in mortality after 48 hours should be an area of interest for quality improvement efforts. More efficient rescue from major complications may help overall trauma mortality rates.

This study has several limitations that must be acknowledged. First, the cause of death is not captured within the MTQIP data and the rate of autopsy, which would allow a definitive cause of death to be determined, and is low in trauma patients. Second, we excluded complications not identified as "serious" within MTQIP data from the FTR analysis, because of low associated mortality rates. However, it is possible that even minor complications may drive mortality in trauma patients.[24] Third, we were unable to completely ascertain trends and granularity in all treatments performed across the hospitals. It is possible that interventions such as the specific type of operation performed may be related to the development of a complication and contribute to the observed variation in mortality rates.[25] Fourth, we do not have complete information on hospital characteristics that may impact outcomes such as nurse to patient ratios, or whether the intensive care units use a closed or open model of care, and hence could not account for these variables in our risk-adjustment models.[26,27] A potential future study is to identify qualitative and quantitative processes present in high-performing hospitals with low FTR rates that allow for prevention of complications or prompt identification and rescue of patients with complications.

AUTHORSHIP

N.F.S., L.G., B.W.O., and M.R.H. contributed in the study conception and design. N.F.S., L.G., A.H.C.-N., and M.R.H. contributed in the acquisition, analysis, or interpretation of data. N.F.S., L.G., and M.R.H. contributed in the drafting of the manuscript. N.F.S., L.G., B.W.O., A.H.C.-N., J.W.S., and M.R.H. contributed in the critical revision of the manuscript for important intellectual content. N.F.S., L.G., A.H.C.-N., and M.R.H. contributed in the statistical analysis. N.F.S. and M.R.H. contributed in the study supervision.

DISCLOSURE

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