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The Location and Timing of Failure-to-Rescue Events Across a Statewide Trauma System

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Abstract

Background: Failure to rescue (FTR) refers to death after a major complication. Defining the optimal context in which to reduce FTR after injury requires knowledge of where and when FTR events occur.

Materials and methods: Retrospective observational study of patients >16 y with a minimum Abbreviated Injury Score ≥ 2 at all 30 level I and II Pennsylvania trauma centers (2007–2015). Location and timing of the first major complication were collected. Complication, mortality, and FTR rates were calculated by location (prehospital, emergency department, operating room, stepdown unit, interventional radiology, intensive care unit (ICU), radiology, and the surgical ward) and by postadmission day. Kruskal–Wallis and chi-squared tests were used to compare variables.

Results: Major complications occurred in 15,388 of 178,602 (8.6%) patients. The median age was 58 y (interquartile range [IQR] 37–77 y), 78% were Caucasian, 68% were male, 89% were bluntly injured, and the median Injury Severity Score was 19 (IQR 10–29). Death occurred in 2512 of 15,388 patients with a major complication, for an FTR rate of 16.3%. Compared with non-FTR, FTR had earlier major complications (median day 2 [IQR 0–5 d] versus day 4 [IQR 2–8 d], $P < 0.001$). FTR rates were highest in the prehospital setting (42%), the operating room (33%), and the emergency department (32%), but the greatest number (1608 of 2512 total FTR events, 64%) occurred in the ICU. Pulmonary (32%) and cardiac (26%) complications most frequently contributed to FTR deaths.

Conclusions: Interventions designed to reduce FTR after injury should focus on pulmonary and cardiac complications in the ICU.

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Disclosure

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

Keywords

Failure to rescue; Trauma; Clinical outcomes; Quality of care

Introduction

Failure to rescue (FTR) is defined as death after a major complication. FTR is a center-level metric that captures the ability of a hospital to identify and successfully manage complications when they occur. First shown by Silber *et al.* to be important in evaluating hospital variations in elective surgical care,¹ FTR has now been used as an important metric across several specialties including trauma.^{2,3} Comparison of FTR rates across trauma centers has shown that not all centers provide equivalent care. High-quality (low-mortality) trauma centers have lower FTR rates than low-quality (high-mortality) centers,³ suggesting centers that provided higher- quality care are better at recognizing and responding to complications that could otherwise lead to death.

FTR is not only useful in comparing care between trauma centers but also it may provide important insight into variations in quality of care that exist within an individual center. Although the epidemiology of death and complications after injury has been well studied,⁴⁻⁸ the location of FTR events along the care pathway is less clear. We recently examined the location and timing of FTR events in a single urban trauma center and found that the highest number of FTR events occurred in the intensive care unit (ICU) early after injury.⁹ As FTR events relate to potentially modifiable hospital-level factors,^{1,3,10} identifying the location and timing of FTR events provides a significant opportunity for quality improvement efforts to be focused on specific locations within a center with the intention of reducing the rate of possibly preventable death.

In this study, we aimed to validate our single-site findings of the location and timing of FTR events using a statewide trauma center data set. We hypothesized that the highest number of FTR events would be found in the ICU. We also hypothesized that cardiac and pulmonary complications would be the highest fractional contributors to FTR rates, as they were in our single-institutional study.

Materials and methods

Study population

We conducted an observational retrospective cohort study using the Pennsylvania Trauma Systems Foundation (PTSF) Trauma Registry Data Set (PTOS) from 2007 to 2015. PTSF is responsible for accreditation and quality of trauma centers in Pennsylvania. PTOS is a prospectively collected statewide trauma database that mandates submission of over 1200 data elements for each patient from all accredited trauma centers in Pennsylvania. PTOS data include prehospital elements, patient demographics, as well as clinical and outcomes data. As data quality is linked to accreditation, centers are strongly incentivized to accurately report data. Importantly, and unlike national trauma registries, each complication that occurs in the PTOS registry is time and location stamped, allowing for a granular understanding of

complication occurrence. Our study included all Pennsylvania level I and II trauma centers. Patients aged >16 y with a minimum Abbreviated Injury Score of 2 were included in the study. Patients with burn injury were excluded. Because the timing and location of the index complication could not be reliably determined within the data set for transferred patients and because transfer patients are often different patient populations, both emergency department (ED) and inpatient transfers ($n = 119,098$) were also excluded. Rates of data missingness were low, ranging from 0.01% for patient sex to 9% for admission Revised Trauma Score (RTS). As this was felt to introduce minimal rates of bias, missing data were excluded.

Exposure

The timing and location of complications were ascertained prospectively by trained nurse abstractors using PTSF definition criteria as specified in the PTOS operational manual (available online at http://www.ptsf.org/upload/2014_PTOS_Manual_Tab_1_through_4_Final.doc).¹¹ We defined major complications as those used in the original published FTR studies (cardiac, pulmonary, renal dysfunction, stroke, wound infection, return to operating room [OR], transfer to ICU)¹ and those found to be associated with mortality in our data in univariate logistic regression analysis with $P < 0.10$.⁹ We grouped major complications into broad categories (pulmonary, cardiac, infectious, hematologic, iatrogenic, and other) to facilitate analysis.⁹ Pulmonary complications in our study included adult respiratory distress syndrome, acute respiratory failure, aspiration pneumonia, atelectasis, pneumonia, pleural effusion, and unplanned intubation. Cardiac complications included myocardial infarction, arrhythmia, and cardiopulmonary arrest. Infectious complications included empyema, sepsis, septicemia, urinary tract infection, and wound infection. Hematologic complications included pulmonary embolism, deep venous thrombosis, transfusion reaction, and coagulopathy. Iatrogenic complications included pneumothorax, aortic occlusion, hypothermia, postoperative hemorrhage, mainstem bronchus or esophageal intubation, decubitus ulcer, and organ/nerve/vessel injury. Other complications included acute kidney failure, hepatic failure, stroke, seizure, gastrointestinal bleeding, unplanned return to OR and unplanned admission to the ICU. RTS was used as a proxy of physiologic derangement upon presentation.

Outcome

FTR was defined as death after a major complication. Patients who survived after developing major complications were defined as “non-FTR.” FTR rates were calculated as the number of FTR events over the total number of patients who developed major complications at each location. For patients who sustained more than one complication, the index complication was used to define entry into the FTR cohort.¹

Data analysis

Descriptive statistics were used to compare baseline demographic variables (age, sex, race) and clinical variables (mechanism of injury, RTS, and injury severity as measured by the Injury Severity Score [ISS]) between FTR and non-FTR cases. Complication, mortality, and FTR rates were calculated and examined by location (prehospital, ED, OR, step-down unit, interventional radiology, ICU, radiology department, surgical ward) and by postadmission

day. Kruskal-Wallis and chi-squared tests were used to compare outcomes across FTR and non-FTR. The fractional contribution of each group of complications to mortality was calculated as the overall number of complications in the group multiplied by the group-specific mortality. The distribution of timing of the first major complication was examined by histogram and statistically assessed using the Mann-Whitney test. All hypothesis tests were two-sided with a significance threshold of $P < 0.05$. Data analysis was performed using the Stata IC/14.1 software (Stata Corporation, College Station, TX). This study was approved by the University of Pennsylvania Institutional Review Board.

Results

We identified 178,602 patients who met inclusion criteria over a 9-y period at 30 level I and II Pennsylvania trauma centers (Fig. 1). Major complications occurred in 15,388 (8.6%) patients. Patients with complications had a median age of 58 y (interquartile range [IQR] 37–77 y), 78% identified as Caucasian, and 68% were male. Almost all (89%) patients sustained blunt injury, with a median ISS of 19 (IQR 10–29) (Table).

Death occurred in 2512 of 15,388 patients with a major complication, for an FTR rate of 16.3%. Patients who died after complications were older than those who survived (median 69 y [IQR 45–82 y] *versus* 56 y [IQR 36–76y], $P < 0.001$) and had a higher injury burden (median ISS 25 [IQR 14–33] *versus* 18 [IQR 10–27], $P < 0.001$). There were no differences in race or sex between FTR and non-FTR cases (Table).

FTR rates were highest in the prehospital setting (43%), the OR (33%), and the ED (32%), but the greatest number of FTR cases occurred due to major complications in the ICU (1608 of 2,512, 64%) (Fig. 2). FTR rates were lowest in the stepdown unit (10%) and the surgical ward (8%).

Complications in FTR cases occurred earlier than complications in non-FTR cases (median 2 d [IQR 0–5 d] *versus* 4 d [IQR 2–8 d], $P < 0.001$) (Fig. 3). The most frequently occurring complications overall were pulmonary ($n = 6255$; 40%) and cardiac ($n = 3341$; 21%), whereas the most lethal complications overall were bleeding/clotting (49% mortality rate) and cardiac (20% mortality rate). After combining the frequency and mortality of specific groups of complications, we found that the complications that had the highest fractional contribution to mortality were pulmonary (32% of FTR deaths) and cardiac (26% of FTR deaths) (Fig. 4).

Discussion

In this statewide study of the location and timing of FTR deaths in trauma patients, we found that deaths after major complications occurred early in the hospital course, with the highest FTR rates occurring in the prehospital setting, the ED, and the OR. However, the highest absolute number of deaths after major complications occurred in the ICU. Specific types of complications (cardiac and pulmonary) most frequently contributed to FTR deaths. Our findings build on our prior institutional study, which found that the highest FTR rates were in the earliest settings after injury, while the highest absolute number of FTR events occurred in the most monitored setting (ICU).⁹ Although prior studies of FTR in trauma

have shown an association between lower FTR rates and higher hospital quality,³ this system-wide study is the first to determine both the sites and timing of FTR events within the course of trauma care.

Our finding that FTR rates were highest in settings early after injury reflects the fact that survival after injury is significantly compromised by additionally sustaining a complication. This is concordant with the extensive evidence on early death after injury.^{8,12,13} However, in contrast to many of these studies, our study only describes those patients who had complications after injury. The American College of Surgeons Committee on Trauma has recognized the impact of reducing early complications after injury, recently publishing evidence-based guidelines for prehospital trauma care including the management of external hemorrhage control and analgesia administration with the goal of standardizing care and decreasing complications including multiple organ failure that most commonly leads to delayed death.^{14,15} The impact of these guidelines on FTR rates in early settings after injury are not yet known but is an area of intended future research.

That more than half of complications leading to FTR deaths occurred in the ICU is also not unexpected. ICUs provide specialized care for the most critically ill patients,¹⁶ and these patients are likely to develop complications.^{17–19} As this is a retrospective study, we cannot say with certainty why FTR events occur most frequently in the ICU, but several bodies of evidence suggest areas for further investigation and possible improvement. Although the physiologic monitoring is most intense in the ICU,¹⁶ it is possible the interface between monitoring and clinician recognition of adverse events is not optimized under current paradigms. Paine et al. recently showed that less than 25% of patient-monitoring alarms in the ICU are actionable,²⁰ which can lead to alarm fatigue and negatively impact provider response times.^{21,22} To combat alarm fatigue, intelligent computer systems that triage device alarms and analyze vast amounts of patient physiologic data have been incorporated into new “smart ICUs” in recent years with the goal of supplementing traditional monitoring systems and improving ICU workflow,²³ but the impact of these interventions on FTR rates in the ICU has yet to be characterized.

It is also possible that strained ICU staffing across hospitals may contribute to a lack of identification and successful management of complications in trauma patients. Intensivist-staffed ICUs have been associated with lower morbidity and mortality.²⁴ However, the number of critical care physicians has not kept pace with the expansion in size and occupancy of ICUs,²⁵ leading to workforce shortages that result in overburdened intensivists.²⁶ Increasing the implementation of technological advancements such as ICU telemedicine programs, which have been shown in a recent prospective study to decrease both mortality and the occurrence of preventable complications in the ICU,²⁷ may serve to alleviate overburdened ICUs and decrease FTR events. Telemedicine innovations have also been shown to improve task-based communications among trauma ICU clinicians,²⁸ which is a critical component of best patient care practices to prevent complications.

Although designing a smart ICU is costly, complex, and requires a dedicated team,²⁹ our findings suggest that focusing resources on improved ICU monitoring and workflow may be worth the investment. In contrast, the comparatively low FTR rate on the surgical ward

suggests that further expanding ward-based early-warning systems used to predict clinical deterioration, which have had mixed evidence to support their ability to improve overall mortality and length of hospital stay,^{30,31} may have little benefit in reducing FTR events in cohorts of injured patients.

Preventability of death after injury also remains an important question in studying FTR in trauma cohorts. Recent evidence suggests that not all deaths classified as FTR in trauma are actually preventable. Kuo *et al.* showed that 75% of trauma deaths that qualified as FTR at a level I urban academic trauma center were deemed non- preventable after adjudication by an expert mortality review panel.³² Coates et al. similarly showed in a single-center study that only 9 of 53 FTR deaths in trauma patients who underwent emergent operations were deemed preventable after adjudication.³³ Both studies advocate for inclusion of some measure of death preventability in FTR calculations to improve the accuracy and usability of the metric when applied to trauma cohorts.

Our study has some limitations, including the inherent limitations of performing a retrospective observational study. Our use of the PTOS registry as our data source, which is collected with the express purpose of studying complications and mortality in trauma, minimized some of the innate challenges of working with administrative data sets. Although the registry portion of the data for this study was collected in a rigorous prospective fashion, we cannot say with complete certainty that all complications were correctly ascertained, and misclassification of complications could influence the apparent rates of FTR. The likelihood of correct exposure ascertainment in our study is higher through our use of PTOS, in which data quality is linked to trauma center accreditation, in comparison to national trauma registries where complications are often undercoded and reporting quality is highly variable among centers.^{34,35} The limitation of using PTOS is generalizability. Although our statewide findings validate our prior single-center study of FTR timing and location, the findings in Pennsylvania trauma centers may not be generalizable to other parts of the country where different patient populations and different regional policies exist. In addition, PTOS does not include postdischarge information, as such patients who died after discharge or those who suffered an FTR event after being readmitted were not captured. As in other FTR studies, the index complication was used to define FTR without knowing whether this complication was directly responsible for mortality. Although this is standard practice for FTR research,^{1,36} it does not account for the interplay between the index complication, subsequent complications, and mortality.³⁷ Complications in FTR analyses are weighted equally, which may not fully control for the treatability of different complications and may underplay the complex relationship between patient, complication, and subsequent deterioration.³⁷ Finally, some patients classified as having an ICU complication in our study may have developed the complication at an earlier location within the trauma center (ED, OR, surgical ward), which prompted ICU admission but was not documented until the ICU location.

Conclusions

We found significant variations in the location and timing of FTR events across a statewide trauma system, with the highest FTR rates occurring in the early phases of trauma care but the majority of FTR events occurring in the ICU. Pulmonary and cardiac complications were

the most common complications in FTR deaths. Quality improvement efforts to reduce deaths after complications in trauma patients should focus on improving the identification and management of complications in the ICU setting.

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Fig. 1 –.

Creation of study cohort. Data were obtained from the Pennsylvania Trauma Systems Foundation (PTSF) Trauma Registry Data Set (PTOS) from 2007 to 2015. FTR indicates failure to rescue (the probability of death after a major complication).

Fig. 2 –.

FTR occurrences and FTR rates by location. FTR occurrences represent the total number of FTR deaths, whereas FTR rate represents the proportion of FTR deaths among those who suffer a major complication at each location.

Fig. 3 –.
Comparison of day of complication in FTR and non-FTR patients. Complications occurred earlier for FTR patients, with a median of 2 d (IQR 0–5 d) compared with 4 d (IQR 2–8 d) for non-FTR patients ($P < 0.001$).

Fig. 4 –.
Fractional contribution of major complication categories to mortality in FTR patients.
Mortality contribution by complication type for 2512 patients who died after a major complication.

Table –

FTR and non-FTR Patient Characteristics.

Variable	Major complications		Non-FTR		FTR		P
	n = 15,388		n = 12,876		n = 2512		
Age, median (IQR), y	58 (37–77)		56 (36–76)		69 (45–82)		<0.001
Male sex, n (%)	10,495 (68)		8746 (68)		1749 (70)		0.10
Race, n (%)							0.05
African American	2493 (16)		2083 (16)		410 (16)		
Caucasian	11,973 (78)		10,045 (78)		1928 (77)		
Asian	139 (1)		106 (1)		33 (1)		
Other/Unknown	783 (5)		642 (5)		141 (6)		
Blunt mechanism of injury, n (%)	13,735 (89)		11,475 (89)		2214 (88)		<0.001
Revised Trauma Score, median (IQR)	7.84 (6.90–7.84)		7.84 (6.90–7.84)		7.84 (5.03–7.84)		<0.001 [*]
Injury Severity Score, median (IQR)	19 (10–29)		18 (10–27)		25 (14–33)		<0.001 [*]
Major complication category, n (%)							<0.001
Pulmonary	6255 (41)		5452 (42)		803 (32)		
Infectious	915 (6)		808 (6)		107 (4)		
Hematologic	506 (3)		258 (2)		248 (10)		
Cardiac	3341 (22)		2678 (21)		663 (26)		
Iatrogenic	2026 (13)		1734 (14)		292 (12)		
Other	2345 (15)		1946 (15)		399 (16)		

^{*} Kruskal-Wallis test.