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Original Contribution

Role of ED crowding relative to trauma quality care in a Level 1 Trauma Center

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ABSTRACT

Objective: Trauma Quality Improvement Program participation among all trauma centers has shown to improve patient outcomes. We aim to identify trauma quality events occurring during the Emergency Department (ED) phase of care.
Methods: This is a single-center observational study using consecutively registered data in local trauma registry (Jan 1, 2016–Jun 30, 2017). Four ED crowding scores as determined by four different crowding estimation tools were assigned to each enrolled patient upon arrival to the ED. Patient related (age, gender, race, severity of illness, ED disposition), system related (crowding, night shift, ED LOS), and provider related risk factors were analyzed in a multivariate logistic regression model to determine associations relative to ED quality events.
Results: Total 5160 cases were enrolled among which, 605 cases were deemed ED quality improvement (QI) cases and 457 cases were ED provider related. Similar percentages of ED QI cases (10–12%) occurred across the ED crowding status range. No significant difference was appreciated in terms of predictability of ED QI cases relative to different crowding status after adjustment for potential confounders. However, an adjusted odds ratio of 1.64 (95% CI, 1.17–2.30, $p < 0.01$) regarding ED LOS ≥2 h predictive of ED related quality issues was noted when analyzed using multivariate logistic regression.
Conclusion: Provider related issues are a common contributor to undesirable outcomes in trauma care. ED crowding lacks significant association with poor trauma quality care. Prolonged ED LOS (≥2 h) appears to be linked with unfavorable outcomes in ED trauma care.

1. Introduction

Quality Improvement (QI) review is a fundamental feature of contemporary medical practice [1]. Recognition of quality issues resulting in undesirable outcomes is not intended to be punitive to healthcare providers but rather serves to continue the dialogue and investigative process resulting in future clinical practice standardization, improvement, and guidance [2]. Therefore, QI evaluation processes are routinely applied in clinical practice across the nation. Similarly, the Trauma Quality Improvement Program (TQIP) is advocated by the American College of Surgeons at Level 1 Trauma Centers as a fundamental aspect of and critical step in trauma center certification [3].

The TQIP model was initiated to improve the quality of trauma care delivery in the United States and was validated as a risk-adjusted outcomes model for the prediction of mortality and comorbidities among all trauma patients [4]. TQIP offers the potential for better trauma care delivery and advocates constant review as a means to discover ongoing areas for trauma care improvement [5]. TQIP cases are commonly categorized based on opportunity for improvement relative to the location of undesirable outcome event location to include prehospital, Emergency Department (ED), and inpatient settings. Most trauma patients are initially seen in the ED which explains why many studies are focused on improving trauma care quality during the ED phase of care and why this time interval has been tightly integrated with TQIP in the past years [6,7].

ED crowding has become more and more common in the US during recent years. This is especially true among EDs with high volume patient encounters, EDs sponsoring residency programs, and EDs with a Level-1 Trauma Center designation [8,9]. Crowding usually increases patient waiting times, delays providers in completing initial medical screening and emergent patient treatment actions, and subsequently impacts patient satisfaction and overall ED operations efficiency [10,11]. Given the

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team approach to trauma care witnessed in Level 1 Trauma Centers, ED crowding may initially appear to have little influence on quality of care delivered to trauma patients. However, a previous trauma quality study showed generally poor performance regarding damage-controlled resuscitation among major trauma patients occurred at times when the ED was in crowded status mode. This was most notable relative to delayed initiation of blood transfusion and emergent procedures [12]. Other undesirable outcomes of ED crowding were related to delays in transfer of care from ambulance crews to ED staff among trauma patients, increased incidence of pneumonia among intubated trauma patients, and poor quality of care among elderly patients with hip fractures [13-16].

Very few studies within the current literature address undesirable events among trauma patients occurring during the ED phase of care as directly linked to ED crowding. TQIP is an important model for predicting patient care outcomes and serves as a catalyst for proposing future state models that advance acute trauma care. Given the continued uptrend in ED crowding across the nation and its negative overall impact on care delivery, application of TQIP principles to identify relevant associations contributing to undesirable trauma care quality appears to be a promising pathway that will deliver meaningful solutions. Therefore, we aim to investigate undesirable outcomes in trauma patient care among the entire local trauma registry data base during the study period Jan 1, 2016 through Jun 30, 2017 to determine the existence of direct associations between quality of care delivered and ED crowding.

2. Methods

2.1. Study design

This is a single center retrospective observational cohort study. The study hospital is a Level 1 Trauma Center and urban tertiary referral center. The study ED has an annual volume of over 120,000 visits. This study was approved by the local Institutional Review Board.

2.2. Study participants

We included all consecutive severe trauma patients during the period Jan 1, 2016 through June 30, 2017 whose data were prospectively collected and placed in a local trauma registry by dedicated trauma coordinators. Severe trauma patients are defined as patients whose conditions meet the trauma center activation criteria which is consistent with the American College of Surgeons Trauma Activation Criteria [17]. Additionally, other trauma patients who were consulted to the Trauma Service during ED encounter or admitted to the Trauma Service from inpatient status while in hospital were also included in the local trauma registry. The study excluded minor trauma patients who did not meet trauma center activation criteria and were subsequently discharged from the ED without consulting the Trauma Service as this cohort did not require TQIP review.

2.3. Quality care events

All patients who were entered the local trauma registry were reviewed by the Trauma Quality Committee. Details of quality case evaluations are shown in Appendix – Methodology. After extensive review, cases were determined to be: 1) acceptable; 2) acceptable with reservations; 3) needed improvements; or 4) unknown/not applicable. Acceptable cases were defined as appropriate, no evident concerns about quality of care; acceptable with reservations defined as quality concern that did not affect the patient's well-being and was unlikely to cause an adverse effect on the patient; needed improvement cases were defined as quality concerns that did not affect the patient's well-being but had the potential to cause an adverse effect or quality concerns that had an adverse effect on the patient, and such cases were referred to as quality improvement (QI) cases. These QI cases were further analyzed in this study.

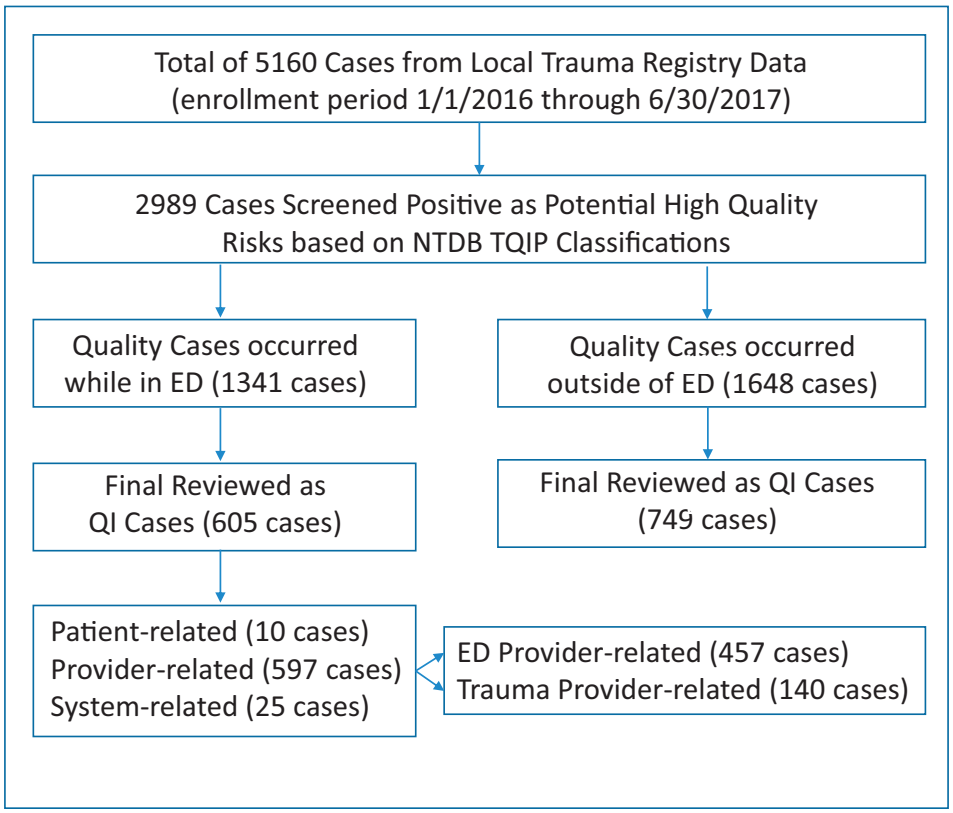

Fig. 1. Trauma quality cases flow diagram.

2.4. ED crowding measurement

ED crowding was measured using four different crowding estimation tools including: 1) NEDOCS (National Emergency Department Overcrowding Scale) [18]; 2) SONET (Severely-overcrowded Overcrowded and Not-overcrowded Estimation Tool) [19]; 3) EDWIN (Emergency Department Work Index) [20]; and 4) ED Occupancy Rate [21]. ED crowding was measured at the top of each time interval (hour) separately throughout the study period. Crowding scores estimated at the beginning of each interval assessment were applied for all subjects who arrived throughout the interval. Based on patient arrival time, each patient was assigned four different ED crowding scores as calculated by the four different crowding estimation tools. Details of ED crowding measurements for each patient are shown in Appendix – Methodology.

2.5. Study protocol

The study patient population was divided into the following three groups: 1) patients with no quality events; 2) patients with QI events occurring during the ED phase of care; and 3) patients with QI events occurring outside of the ED phase of care. Group analysis of general patient information (age, gender, race) and clinical variables (severity of illness, ED length of stay (LOS), trauma level activation, and ED disposition) were compared among these three groups. Quality cases (patient illness related, system related, and provider related) were compared relative to events occurring during the ED phase of care or outside the ED phase of care groups. Furthermore, ED crowding was analyzed specifically to determine whether crowding is directly linked to ED QI events. Since no gold standard currently exists to measure ED crowding, we used four different crowding estimation tools. To avoid confounding factors, ED crowding was also analyzed after adjusting for other variables in a multivariate logistic regression model.

2.6. Data analysis

Student's *t*-test was used to compare continuous variables between two groups, while Pearson Chi-square ($\chi 2$) analysis was used to compare categorical variables. Analysis of variance (ANOVA) with Bonferroni correction was used to analyze differences between groups. To minimize the confounders, ED crowding status was analyzed along with other variables (general patient information and clinical variables) as potential independent risk factors predictive of ED QI events in a multivariate logistic regression model. Variables selected for inclusion in this multivariate logistic regression model were age, gender, race, injury severity score (ISS), trauma and injury severity score (TRISS), ED LOS, ED disposition, trauma activation level, patient arrival window (day versus night), and ED crowding status. Since four different ED crowding estimation tools were used in this study, four multivariate logistic regression models were built with each model consisting of one ED crowding score as determined by a specific crowding tool separately. After identifying the potential risks predictive of ED QI events, a receiver operating characteristics (ROC) curve was drawn to determine the optimal cutoff point for such risks. All descriptive and statistical analyses were performed using Stata 14.2 (College Station, TX). A p value <0.05 was considered statistically significant.

3. Results

A total of 5160 cases were involved in the QI evaluation. Of these, 58% (2989/5160) were screened as positive due to high quality risk potential based on the NTDB TQIP classifications thereby triggering further trauma quality review and discussion. Among these high-quality risk cases, 45% (1341/2989) occurred in the ED. Final review and discussion among members of the local Trauma Quality Committee yielded a group of 605 cases deemed as concerns on quality of care delivery (Fig. 1). We further divided QI cases relative to location as those occurring during the ED phase of care versus those occurring outside of the ED phase of care and compared them with cases deemed to have no concerning quality issues. ED QI cases tended to occur with greater frequency among patients who were older and experienced greater ED LOS. Additionally, 76% (457/605) of ED QI cases were deemed to be ED provider related, whereas only 4% (25/605) and 2% (10/605) cases were considered system or patient related separately. Details are shown in Table 1.

We further analyzed the association between ED quality cases and ED crowding. Approximately 12% of cases were considered ED QI cases regardless of ED crowding status as demonstrated consistently across all four crowding measurements (Table 2). Given the association between ED QI cases with respect to ED provider related issues, a special analysis of ED crowding and ED provider related ED QI cases was performed yielding similar findings in comparison to all ED unacceptable quality cases (Table 2) indicating no direct association between ED crowding and ED quality cases.

To avoid confounding factors, a multivariate logistic regression analysis was performed to determine the risks predictive of all ED QI cases. After adjusting for all variables, our findings again indicated that ED crowding is not considered an independent risk for ED quality case predictions regardless of the specific crowding estimation tool employed

Table 1
General information of study population.

	ED QI cases (N = 605)	QI cases outside ED (N = 749)	Cases without quality issues (N = 3806)
Patient general characteristics			
Age (median, IQR), years	44 (28–59)	40 (26–58)	38 (25–55)
Gender (n, %)			
Male	410 (68)	530 (71)	2639 (69)
Female	195 (32)	219 (29)	1167 (31)
Race (n, %)			
White	358 (59)	464 (62)	2006 (53)
Black	101 (17)	115 (15)	782 (21)
Others[a]	146 (24)	170 (23)	1018 [27]
Time arrived at ED (n, %)			
Day (7a–7p)	315 (52)	365 (49)	1977 (52)
Night (7p–7a)	290 (48)	384 (51)	1829 (48)
Clinical variables			
Trauma activation level (n, %)			
Level 1	61 (10)	161 (22)	685 (18)
Level 2	212 (35)	268 (36)	1854 (49)
Level 3	237 (39)	225 (30)	943 (25)
Unknown	95 (16)	95 (13)	324 (8.5)
ISS (median, IQR)	8 (4–10)	9 (4–13)	5 (1−12)
TRISS (median, IQR)	0.992 (0.97–0.996)	0.99 (0.968–0.994)	0.993 (0.972–0.996)
ED LOS (median, IQR), minutes	314 (181–488)	217 (100–347)	240 (137–371)
ED disposition (n, %)			
Death	1 (0.2)	0 (0)	79 (2.1)
OR	91 (15)	124 (17)	359 (9.4)
ICU	81 (13)	176 (24)	595 (16)
Admission (Non-ICU)	372 (61)	361(48)	1230 (32)
Home	48 (7.9)	83 (11)	1315 (35)
Others[b]	12 (2.0)	5 (0.7)	228 (6.0)
Quality issue variables			
Patient-related (n, %)	10 (1.7)	27 (3.6)	
System-related (n, %)	25 (4.1)	44 (5.9)	
Provider-related (n, %)	597 (99)	724 (97)	
ED Provider-related (n, %)	457 (76)		

[a] Including Asian, Native American, or Unknown.
[b] Including transfer to other facilities (correctional facility, court/law enforcement, mental health, psychiatric hospital, rehab or skilled nursing facility, burn center, and labor and delivery, etc.), left against medical advice, or not applicable.

Table 2
Association between ED crowding and ED related quality cases.

	ED provider related ED QI cases		All provider related ED QI cases	
	Yes (N = 457)	No (N = 4703)	Yes (N = 605)	No (N = 4555)
NEDOCS (n, %)				
Not crowded (0−100)	155 (8.9)	1584 (91)	215 (12)	1524 (88)
Crowded (101–140)	119 (8.5)	1274 (91)	157 (11)	1236 (89)
Overcrowded (140–200)	183 (9.0)	1845 (91)	233 (11)	1795 (89)
SONET (n, %)				
Not crowded (0–100)	185 (9.0)	1879 (91)	257 (12)	1807 (88)
Crowded (101–140)	191 (8.8)	1992 (91)	240 (11)	1943 (89)
Overcrowded (141–200)	81 (8.9)	832 (91)	108 (12)	805 (88)
EDWIN (n, %)				
Not crowded (0–1.55)	332 (8.9)	3412 (91)	448 (12)	3296 (88)
Crowded (1.55–1.83)	55 (8.2)	620 (92)	69 (10)	606 (90)
Overcrowded (>1.83)	70 (9.5)	671 (91)	88 (12)	653 (88)
ED occupancy rate (n, %)				
Not crowded (0–1.2)	185 (8.8)	1915 (91)	251 (12)	1849 (88)
Crowded (>1.2)	272 (8.9)	2788 (91)	354 (12)	2706 (88)

NEDOCS: National Emergency Department Overcrowding Scale; SONET: Severely-overcrowding Overcrowding Not-overcrowding Estimation Tool; EDWIN: Emergency Department Work Index.

(Table 3). However, the adjusted odds ratio of prolonged ED length of stay ≥2 h predicting ED QI cases was 1.64 indicating a potential marker for ED quality improvement control. Meanwhile, a histogram was drawn to determine the association between ED QI cases and patient total ED LOS. It showed that increased ED QI cases positively associated with prolonged patient ED LOS (Fig. 2A). When a threshold line of missing <20% of ED QI cases was drawn, only patients whose ED LOS <2 h met such requirement. Additionally, a receiver operating characteristic (ROC) curve was developed showing a similar trend toward predicting ED QI cases if the cutoff of ED LOS was set as 2 h (Fig. 2B). Therefore, our study demonstrated consistent findings of using ED LOS predicting ED QI cases (Fig. 2).

4. Discussion

The potential risks associated with poor quality trauma care delivery are varied [22,23]. ED trauma quality control acts as an important step in the assessment of overall trauma quality events since poor quality trauma care has been linked to negative patient care outcomes [6,24]. Our study focused on investigating ED trauma quality events and specifically identified its association with ED crowding. Our results indicate that nearly half of these trauma quality events occurred during the ED phase of care indicating the importance of establishing trauma quality control in the ED. Though ED crowding demonstrated little influence on ED trauma quality predictions, prolonged ED LOS (≥2-h) appeared to be associated with unfavorable outcomes in ED trauma care. Such findings suggest that ED LOS can be used as a quality marker to drive process changes that improve overall quality of care delivered to trauma patients during their ED phase of care.

Though it is well known that rapid ED evaluation and treatment is critical in severe trauma patients [25,26], current national trauma activation criteria do not contain a universal time interval within which level-specific trauma activations must occur. Neither does a standard interval exist for timely ED trauma transfers. Our results indicate that ED crowding rarely affects ED trauma quality care. As such a Level 1 Trauma Center's refusal to accept a trauma transfer simply based on ED crowding might not be appropriate. We believe our findings add evidence to the literature pool in terms of: 1) recognizing the importance of initiating continuous ED trauma quality assessment; 2) validating the link between ED crowding and trauma care; and 3) further supporting the need for timely acute trauma care in the ED. Though this study did not provide direct evidence of patient benefits from timely acute trauma care transfer, it indirectly supports that prolonged ED stays result in overall poor ED trauma care delivery which has been rarely reported to date.

Since prolonged ED LOS has been associated with poor ED trauma care outcomes and ED crowding has been associated with prolonged ED LOS [27], it is worthwhile to determine whether ED crowding affects ED trauma care delivery. Our study failed to support the direct link between ED crowding and poor ED trauma care outcomes. This is probably

Table 3
Adjusted odds ratios of risks predictive of ED trauma quality improvement events using different ED crowding estimation tools.

	Adjusted odds ratios of variables with 95% confidence interval			
	NEDOCS	SONET	EDWIN	ED occupancy rate
ED crowding				
Not crowded	Reference	Reference	Reference	Reference
Crowded	0.92 (0.72–1.19)	0.92 (0.74–1.15)	0.84 (0.61–1.16)	1.01 (0.83–1.24)
Overcrowded	0.98 (0.78–1.23)	1.03 (0.78–1.35)	1.16 (0.89–1.52)	
ED LOS ≥2 h	1.64 (1.17–2.30)	1.64 (1.17–2.30)	1.63 (1.16–2.30)	1.64 (1.17–2.30)
Age	1.00 (1.00–1.01)	1.00 (1.00–1.01)	1.00 (1.00–1.01)	1.00 (1.00–1.01)
Gender				
Male	Reference	Reference	Reference	Reference
Female	1.07 (0.86–1.32)	1.07 (0.86–1.32)	1.06 (0.86–1.32)	1.07 (0.86–1.32)
Race				
White	Reference	Reference	Reference	Reference
Black	0.84 (0.63–1.11)	0.84 (0.63–1.11)	0.84 (0.64–1.11)	0.84 (0.63–1.11)
Others[a]	0.94 (0.74–1.20)	0.94 (0.74–1.20)	0.94 (0.74–1.19)	0.94 (0.74–1.19)
ISS	0.97 (0.96–0.99)	0.97 (0.96–0.99)	0.97 (0.96–0.99)	0.97 (0.96–0.99)
TRISS	1.19 (0.31–4.57)	1.19 (0.31–4.56)	1.21 (0.31–4.66)	1.19 (0.31–4.56)
ED disposition				
Home	Reference	Reference	Reference	Reference
ICU	3.92 (2.43–6.31)	3.91 (2.43–6.31)	3.95 (2.45–6.37)	3.92 (2.43–6.32)
Non-ICU	4.91 (3.42–7.04)	4.90 (3.41–7.04)	4.94 (3.44–7.09)	4.91 (3.42–7.05)
OR	4.91 (3.16–7.62)	4.90 (3.16–7.62)	4.87 (3.13–7.57)	4.92 (3.16–7.64)
Arrival				
Day	Reference	Reference	Reference	Reference
Night	1.03 (0.84–1.25)	1.03 (0.84–1.25)	1.02 (0.84–1.25)	1.02 (0.84–1.25)

Abbreviations: ED, Emergency Department; NEDOCS, National Emergency Department Overcrowding Scale; SONET: Severely-overcrowding overcrowding not-overcrowding Estimation Tool; EDWIN: Emergency Department Work Index; LOS, Length Of Stay; ISS, Injury Severity Score; TRISS, Trauma and Injury Severity Score; ICU, Intensive Care Unit; OR, Operating Room.
[a] Including Asian, Native American, or Unknown.

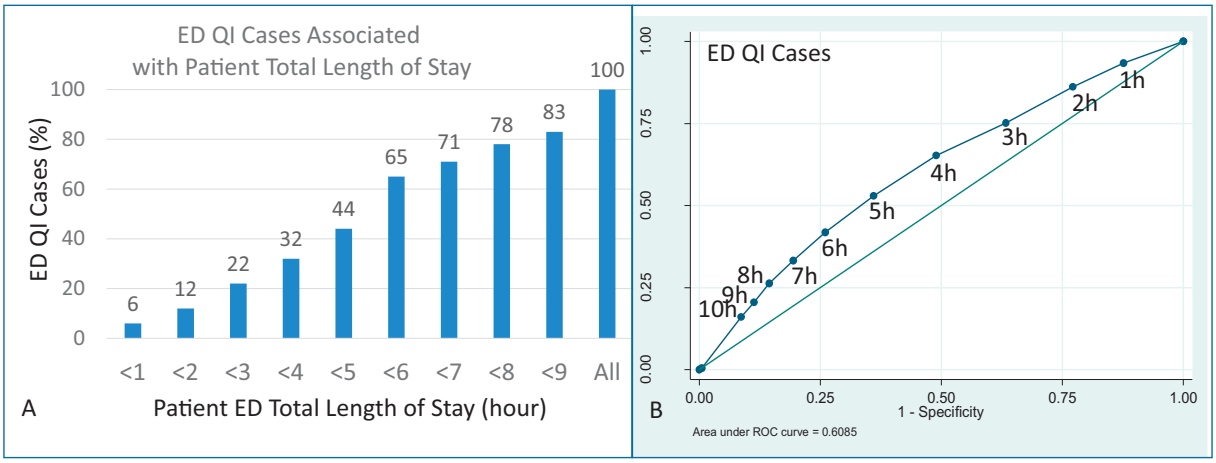

Fig. 2. The Association Between ED QI Cases and Patient Prolonged ED LOS. A) Histogram of Percentage of ED QI Cases Associated with Patient ED Total Length of Stay; B) Receiver Operational Characteristic Curve of ED QI Cases Associated with ED Total Length of Stay among Trauma Patients.

due to the fact that prolonged ED LOS is affected by many factors with ED crowding being one of the causes. On the other hand, since there is no gold standard to determine ED crowding, the commonly used ED crowding tool scales in their current forms might not be entirely accurate. Our study did demonstrate consistent associations between the four individual ED crowding tool measurements and ED trauma quality cases thereby indicated less bias.

Though prolonged ED LOS itself is not a perfect diagnostic marker to predict poor ED trauma care, it can be used as an alert to all members of the Trauma Team since: 1) this is a simple and easy metric to measure and follow in real time; 2) this operations metric is reported nationally through the Emergency Department Benchmarking Alliance, Centers for Medicare and Medicaid Services, and other reporting agencies and tracked locally, regionally, and nationally as a marker of ED efficiency relative to resource demands; and 3) it is practical to automate its utility within any Electronic Medical Record system thereby avoiding the need for additional human resources. Establishing a 2-h window for transfer of care from the ED phase (initial assessment and treatment) to inpatient phase (continued assessment and treatment) of the hospital encounter appears to be a reasonable opportunity to mitigate high-risk quality outcomes among trauma patients. Therefore, we recommend ED LOS ≥2 h should be considered as a meaningful metric relative to risk stratification of ED trauma quality care. Future research should be carried out to validate our findings. Additionally, research at non-trauma centers might be needed to further identify associations between ED LOS and ED trauma care delivered at those facilities.

5. Limitations

This is a single center observational study with potential patient selection bias. Quality cases were reviewed and discussed by the local Trauma Quality Committee and final determinations of acceptable versus need improvement care were made by its members. Though cases were screened based on NTDB TQIP classifications, acceptable versus QI case determinations had the potential to be biased due to lack of a gold standard. Our ED has a dedicated trauma area that reserves two resuscitation bays for emergent resuscitations which might be less affected by ED crowding. Four different crowding estimation tools were used in this study. No gold standard currently exists regarding ED crowding report. Although we noted consistency across the four ED crowding estimation tools in terms of determining ED crowding status relative to ED trauma quality cases, direct linkage remains uncertain without a gold standard calibration method. Some important variables predictive of poor ED trauma care might not be included in our multivariate logistic regression model. Lastly, given the fact of trauma quality cases attributed by multiple factors as shown in Table 3, prolonged ED LOS should not be considered as the only important marker for such predictions. Therefore, due to potential patient population selection bias in a single center study with specific ED setting, a multicenter external validation with large sample size is still warranted.

6. Conclusion

In summary, provider related issues are a common contributor to undesirable outcomes in trauma care. ED crowding lacks significant association with poor trauma quality care. Prolonged ED LOS (≥2 h) appears to be linked with unfavorable outcomes in ED trauma care.

Author contribution

HW conceived the study and designed the protocol. HW, NS, CL, and JK performed the literature search, and data collection. HW, RDR, TMD, SB, and RG performed the data interpretation and analysis. HW, NS, RDR, TMD, JK, SMM, and NRZ drafted the article, providing critical revisions, and all authors contributed substantially to this study. HW takes responsibility for the paper.

Conflict of interests

Authors have no conflict of interests.

Ethical approval statement

This study was approved by the John Peter Smith Health Network Institutional Review Board.

Disclosure of funding received for this work

Authors have no financial disclosures to report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2018.06.029.

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