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Patient and process factors associated with opportunities for improvement in trauma care: a registry-based study

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Abstract

Background Trauma is one of the leading causes of morbidity and mortality worldwide. Morbidity and mortality review of selected patient cases is used to improve the quality of trauma care by identifying opportunities for improvement (OFI). The aim of this study was to assess how patient and process factors are associated with OFI in trauma care.

Methods We conducted a registry-based study using all patients between 2017 and 2021 from the Karolinska University Hospital who had been reviewed regarding the presence of OFI as defined by a morbidity and mortality conference. We used bi- and multivariable logistic regression to assess the associations between the following patient and process factors and OFI: age, sex, respiratory rate, systolic blood pressure, Glasgow Coma Scale (GCS), Injury Severity Score (ISS), survival at 30 days, highest hospital care level, arrival on working hours, arrival on weekends, intubation status and time to first computed tomography (CT).

Results OFI was identified in 300 (5.8%) out of 5182 patients. Age, missing Glasgow Coma Scale, time to first CT, highest hospital care level and ISS were statistically significantly associated with OFI.

Conclusion Several patient and process factors were found to be associated with OFI, indicating that patients with moderate to severe trauma and those with delays to first CT are at the highest odds of OFI.

Keywords Trauma, Opportunities for improvement, Trauma care, Acute surgery

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Introduction

Trauma is one of the leading causes of morbidity and mortality in all age groups globally [1, 2]. There are approximately 4.5 million global deaths each year due to trauma, [3] and it is one of the top contributors to disease burden worldwide, measured by disability-adjusted life years [4, 5]. Trauma is also resource-intensive as it is one of the most common reasons for critical care unit admission [6].

The quality of trauma care can be expressed using Donabedian's quality of care framework, in which improved structures and clinical processes improve

patient outcomes [7]. There are several methods to improve the quality of trauma care, with multidisciplinary morbidity and mortality review being a key method to address all components of this framework [8].

The morbidity and mortality review aims to assess the preventability of patient deaths and to identify opportunities for improvement (OFI) in the structure and clinical processes of trauma care. The rate of OFI in trauma deaths ranges between 20 and 76%, [9–11] and common OFI relates to airway management, management of traumatic brain injury, fluid resuscitation, delays in prehospital transport and delays to surgery [12–15].

Whereas numerous studies assess associations between patient and process factors and mortality, little research exists on how these factors are associated with non-mortality outcomes such as OFI. Understanding these factors can alert clinicians of patient groups prone to experiencing medical errors, and who are likely to benefit from quality improvement efforts, as an adjunct to existing trauma quality improvement programmes.

The aim of this study was to assess how patient and process factors are associated with OFI in trauma care.

Methods

Study design

We conducted a single-center registry-based retrospective cohort study. We used data from the Karolinska University Hospital trauma registry, which reports to the Swedish National Trauma Registry, [16] as well as the hospital's local trauma care quality database. The content of the trauma registry has been previously described [17]. From 2017 and onwards the trauma care quality database includes all patients in the trauma registry as well as the results of the morbidity and mortality review, including identified OFI. We linked the trauma registry and trauma care quality database using personal identification numbers and extracted factors potentially associated with OFI.

Setting

All major trauma patients in the greater metropolitan area of Stockholm are triaged to the Karolinska University Hospital in Solna, which is equivalent to a level one trauma center according to the criteria set by the American College of Surgeons [18]. The hospital has direct access to radiology, intervention, surgery, intensive care and consultants in all associated specialties [19, 20]. All trauma patients presenting to Karolinska University Hospital are included in a morbidity and mortality screening process that combines individual review by specialized nurses and audit filters, shown in Table 1. Patients identified as having a high potential for OFIs are discussed in multidisciplinary conferences. Examples of potential OFIs identified in this screening process include the need for more senior members assisting the trauma team or need for additional emergency operating rooms, which are then categorised into broader categories such as lack of resources and logistics. The multidisciplinary conferences take place every six to eight weeks and last about one hour. During the conferences, an average of ten patient cases are reviewed by experienced specialists from all the disciplines and professions involved in trauma care. The presence or absence of OFI is a consensus decision among all participants of the conference and is recorded in the trauma care quality database.

Participants

The trauma registry includes all patients admitted with trauma team activation, regardless of Injury Severity Score (ISS), as well as patients admitted without trauma team activation but found to have an ISS of more than 9. We included all patients who had been included in the

Table 1 Local audit filters

Audit filter	Number of patient cases flagged 2017–2021*
Systolic blood pressure under 90	87
Glasgow Coma Scale (GCS) less than 9 and not intubated	15
Injury Severity Score (ISS) more than 15 but not admitted to the ICU	516
Injury Severity Score (ISS) more than 15 and no trauma team activation	259
No anticoagulation treatment within 72 h after traumatic brain injury time to acute intervention more than 60 min	211
	823
Time to computed tomography (CT) more than 30 min	2444
Liver or spleen injury	213
Cardiopulmonary resuscitation with thoracotomy	32
Massive transfusion	151
Death within 30 days after trauma	203

*The total number of unique patients flagged was 3416. The sum of the number of patient cases flagged exceeds the number of unique patients flagged because several filters could flag the same patient

morbidity and mortality screening process between January 1, 2017 and June 1, 2021. We excluded patients who were younger than 15 years and patients who were dead on arrival.

Variables
Study outcome
The outcome was the presence of OFI, as decided by the morbidity and mortality conference. An OFI is any failure of care including, but not limited to, any potentially preventable or preventable death, delay in treatment, clinical judgment error, missed diagnosis and technical error as decided by the mortality and morbidity conference. The study outcome is binary with the levels "Yes - At least one OFI identified" and "No - No OFI identified".

Patient and process factors
We selected factors from the trauma registry, based on the locally used audit filters (Table 1), standard epidemiological factors and factors registered in the Swedish National Trauma Registry. The categorical factors were sex, survival after 30 days, highest hospital care level, Glasgow Coma Scale (GCS), respiratory rate, systolic blood pressure, working hours, weekend, time from arrival at the hospital until first computed tomography (CT) and if the patient was intubated. We also included the continuous factors age and ISS, and categorised these using standard cutoffs.

In the trauma registry, both systolic blood pressure and respiratory rate are registered as either a continuous value or a Revised Trauma Score category [21]. We converted the continuous values of systolic blood pressure and respiratory rate, if registered, and GCS score into the corresponding Revised Trauma Score category. If the patient was intubated and missing values for respiratory rate and GCS score, prehospital pre-intubation values were used.

The factor highest hospital care level, defined as the highest level of in-hospital care the patient being admitted to, is divided into five categories: emergency department, general ward, operating theatre, high dependency unit and critical care unit. The category emergency department means that the patient was not admitted, but was either discharged from or died in the emergency department. The category general ward is all wards with no further monitoring. The category operating theatre is assigned to patients who undergo surgery but who are not admitted to a high dependency or critical care unit post-operatively. High dependency units are wards with more extensive monitoring. Patients with multi-organ failure or who require mechanical ventilation are admitted to critical care units.

Factors denoting if the patient arrived at the hospital during working hours were included, defined as between 8.00 a.m. and 5 p.m., or during a weekend, defined as Saturday or Sunday.

Statistical analysis
A complete case analysis was conducted after handling missing values in systolic blood pressure, respiratory rate, and GCS score as described above. We present sample characteristics using descriptive statistics. Bivariable logistic regression was used to determine unadjusted associations and multivariable logistic regression to determine adjusted associations between patient and process factors and OFI. We present odds ratios (OR) with associated 95% confidence intervals. A significance level of 5% was used. The programming language R was used for all analyses [22]. All statistical analysis was first done on synthetic data and later implemented on the data collected from the trauma registry and the trauma care quality database to ensure objectivity.

Results
Out of 5,216 patients included in both the trauma registry and trauma care quality database between 2017 and 2021, 34 patients were excluded, leaving a total of 5,182 patients eligible for the study. 26 out of the 34 patients not eligible for the study because they were dead on arrival. Eight patients were excluded because they were aged less than 15 years or had missing data. The factor with the highest frequency of missing data was Glasgow Coma Scale, for which values were missing in 168 (3.2%) patients, nevertheless those patients were included.

Among the 5,182 patients included, there were 3,416 patients (65.9%) unique patients flagged with potential OFI, and 300 (5.8%) patients with OFI. Table 1 shows the number of patients flagged per audit filter. Sample characteristics are presented in Table 2. A total of 3,520 (68%) patients were male and 2,805 (54%) patients were adults in the age group 25–59 years. Most patients had ISS<9, 2641 (51%). The number of patients who arrived outside of working hours was 3,060 (59.1%), and 1,671 (32.2%) patients arrived during weekends. A total of 203 (3.9%) patients died within 30 days.

The unadjusted and adjusted associations of selected factors with OFI are shown in Table 3.

The following factors were significantly associated with OFI only in the unadjusted analysis: Young adults (aged 20–24 years) (OR 1.88, 95% CI 1.03–3.60, p-value 0.046) and older adults (aged 60–100 years) (OR 2.47, 95% CI 1.48–4.46, p-value 0.001) compared with older adolescents (aged 15–19 years). Intubation in the emergency department compared with no intubation (OR 2.72, 95% CI 1.89–3.83, p-value<0.001). Respiratory rate higher than 29 compared with respiratory rate between 10 and 29 (OR 2.11, 95% CI 1.25–3.37, p-value 0.003). Systolic blood pressure between 50 and 75 (OR 4.05, 95% CI

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Table 2 Sample characteristics

Characteristic	No opportunity for improvement, N = 4,882[1]	Opportunity for improvement, N = 300[1]	Overall, N = 5,182[1]
Sex			
Male	3,309 (68%)	211 (70%)	3,520 (68%)
Female	1,573 (32%)	89 (30%)	1,662 (32%)
Age (years)			
Older adolescents (15–19)	415 (8.5%)	15 (5.0%)	430 (8.3%)
Young adults (20–24)	500 (10%)	34 (11%)	534 (10%)
Adults (25–59)	2,670 (55%)	135 (45%)	2,805 (54%)
Older adults (60–100)	1,297 (27%)	116 (39%)	1,413 (27%)
Intubation			
None	4,459 (91%)	247 (82%)	4,706 (91%)
Pre-hospital	151 (3.1%)	12 (4.0%)	163 (3.1%)
Emergency department	272 (5.6%)	41 (14%)	313 (6.0%)
Highest hospital care level			
Emergency Department	1,116 (23%)	13 (4.3%)	1,129 (22%)
General Ward	1,980 (41%)	67 (22%)	2,047 (40%)
Operating Theater	867 (18%)	92 (31%)	959 (19%)
High Dependency Unit	184 (3.8%)	28 (9.3%)	212 (4.1%)
Critical Care Unit	735 (15%)	100 (33%)	835 (16%)
Respiratory rate			
10–29	4,504 (92%)	267 (89%)	4,771 (92%)
>29	152 (3.1%)	19 (6.3%)	171 (3.3%)
6–9	41 (0.8%)	0 (0%)	41 (0.8%)
1–5	15 (0.3%)	1 (0.3%)	16 (0.3%)
0	23 (0.5%)	0 (0%)	23 (0.4%)
Missing	147 (3.0%)	13 (4.3%)	160 (3.1%)
Systolic blood pressure			
>89	4,766 (98%)	284 (95%)	5,050 (97%)
76–89	63 (1.3%)	9 (3.0%)	72 (1.4%)
50–75	29 (0.6%)	7 (2.3%)	36 (0.7%)
1–49	1 (< 0.1%)	0 (0%)	1 (< 0.1%)
0	11 (0.2%)	0 (0%)	11 (0.2%)
Missing	12 (0.2%)	0 (0%)	12 (0.2%)
Glasgow Coma Scale			
13–15	4,304 (88%)	250 (83%)	4,554 (88%)
9–12	195 (4.0%)	20 (6.7%)	215 (4.1%)
3–8	226 (4.6%)	19 (6.3%)	245 (4.7%)
Missing	157 (3.2%)	11 (3.7%)	168 (3.2%)
Working hours[2]			
Yes	2,002 (41%)	120 (40%)	2,122 (41%)
No	2,880 (59%)	180 (60%)	3,060 (59%)
Weekend[3]			
Yes	1,577 (32%)	94 (31%)	1,671 (32%)
No	3,305 (68%)	206 (69%)	3,511 (68%)
Injury Severity Score			
Mild < 9	2,593 (53%)	48 (16%)	2,641 (51%)
Moderate 9–15	1,335 (27%)	82 (27%)	1,417 (27%)
Severe 16–25	545 (11%)	98 (33%)	643 (12%)
Profound > 25	409 (8.4%)	72 (24%)	481 (9.3%)
Time to first CT			
0–30	1,911 (39%)	95 (32%)	2,006 (39%)
No CT	510 (10%)	24 (8.0%)	534 (10%)
31–60	1,087 (22%)	85 (28%)	1,172 (23%)
61–90	524 (11%)	38 (13%)	562 (11%)

Table 2 (continued)

Characteristic	No opportunity for improvement, N = 4,882[1]	Opportunity for improvement, N = 300[1]	Overall, N = 5,182[1]
>90	850 (17%)	58 (19%)	908 (18%)
Survival after 30 days			
Alive	4,694 (96%)	285 (95%)	4,979 (96%)
Dead	188 (3.9%)	15 (5.0%)	203 (3.9%)

[1] n (%)

[2] Arrival at the hospital between 8.00 a.m. and 5 p.m

[3] Arrival at the hospital on Saturday or Sunday

1.62–8.82, p-value 0.001) and between 76 and 89 (OR 2.40, 95% CI 1.10–4.62, p-value 0.016) compared with a systolic blood pressure of more than 89. Glasgow coma scale 9–12 (OR 1.77, 95% CI 1.06–2.78, p-value 0.020) compared with Glasgow coma scale 13–15.

Compared to care in the emergency department, all higher levels of care were significantly associated with increased odds of OFI in both the unadjusted and adjusted analyses. The highest odds were found in patients treated in a high dependency unit (aOR 8.25, 95% CI 4.02–16.9, p-value < 0.001). Compared to mild trauma (ISS < 9), all other ISS groups had significantly higher odds of OFI, with the highest odds of OFI in those with profound trauma (ISS > 25) (aOR 5.54, 95% CI 3.43–8.96, p-value < 0.001).

A time to first CT between 31 and 60 min was in the unadjusted analysis significantly associated with higher odds of OFI compared with a time to first CT between 0 and 30 min (OR 1.57, 95% CI 1.16–2.13, p-value 0.003). This association remained significant in the adjusted analysis (OR 1.53, 95% CI 1.11–2.10, p-value 0.009), but in this analysis a time to first CT between 61 and 90 min (aOR 2.44, 95% CI 1.60–3.72, p-value < 0.001) and a time over 90 min (aOR 1.60, 95% CI 1.11–2.31, p-value 0.012) were also associated with significantly higher odds of OFI.

Sex, arrival on weekday or weekend and arrival during working hours and survival after 30 days were not significantly associated with OFI in neither the unadjusted nor the adjusted analysis.

Discussion

We found that higher levels of care were associated with increased odds of OFI. Previous research indicates that more than half of the preventable and probably preventable trauma deaths occur in critical care units, [13] and that the most common OFI were related to airway management and perioperative care 23. These findings could be because patients admitted to higher levels of care receive more interventions, increasing the probability of OFI. Similarly, we found ISS to be significantly associated with OFI. This could be because the management of severely injured patients is more complex, and they require more interventions, and that their care is therefore more prone to OFI. Interestingly, the vital signs systolic blood pressure, respiratory rate, and GCS as well as intubation were all significantly associated with OFI in the unadjusted analysis but not in the adjusted analysis. This could be because these factors indicate more severe trauma, which was more effectively captured by ISS in the adjusted analysis.

We also found that time to CT was associated with increased odds of OFI. Delays to CT in trauma patients has in previous studies been associated with poor outcomes, [24] and a study recently made in Japan found that CT within ten minutes after arrival in severe trauma patients was associated with decreased in-hospital mortality [25]. The association between time to CT and OFI is complex because even though life saving interventions need to be prioritised over imaging, this can result in missed injuries for which management is then delayed, potentially resulting in complications. Our finding that no CT was not significantly associated with OFI compared to a time to CT between 0 and 30 min may be because these patients are either so mildly injured that they can be discharged from the emergency department, or that they are so severely injured that they do not survive until CT.

Our study had several limitations. Although all trauma patients were reviewed by specialized nurses, the selection for review by the morbidity and mortality conference relied mostly on audit filters, meaning that there is a risk for misclassification whereby some patients with OFI were not selected for review by the conference and therefore registered as patients without OFI. Another limitation is that several potential relevant clinical factors, such as mental status or airway difficulty, were not available in the registry and therefore not adjusted for in the analysis. Furthermore, this study was a single-center study, and its results illustrate the situation in Stockholm.

Conclusion

The care of patients who require higher levels of care, have more severe trauma, and who's CT is delayed, has significantly higher odds of OFI. These factors represent reasonable targets for new initiatives to supplement ongoing trauma quality improvement efforts.

Table 3 Unadjusted and adjusted logistic regression analyses of associations between patient level factor and opportunities for improvement

Characteristic	Unadjusted			Adjusted		
	OR[1]	95% CI[1]	p-value	OR[1]	95% CI[1]	p-value
Sex						
Male	—	—		—	—	
Female	0.89	0.68, 1.14	0.36	1.04	0.79, 1.36	0.8
Age (years)						
Older adolescents (15–19)	—	—		—	—	
Young adults (20–24)	1.88	1.03, 3.60	**0.046**	1.87	0.98, 3.57	0.058
Adults (25–59)	1.40	0.84, 2.51	0.23	1.25	0.71, 2.20	0.4
Older adults (60–100)	2.47	1.48, 4.46	**0.001**	1.76	0.99, 3.14	0.055
Intubation						
None	—	—		—	—	
Pre-hospital	1.43	0.75, 2.51	0.24	0.93	0.41, 2.09	0.9
Emergency department	2.72	1.89, 3.83	**< 0.001**	1.07	0.66, 1.74	0.8
Highest hospital care level						
Emergency Department	—	—		—	—	
General Ward	2.90	1.65, 5.53	**< 0.001**	2.21	1.16, 4.20	**0.016**
Operating Theater	9.11	5.25, 17.2	**< 0.001**	4.80	2.46, 9.35	**< 0.001**
High Dependency Unit	13.1	6.78, 26.5	**< 0.001**	5.46	2.56, 11.7	**< 0.001**
Critical Care Unit	11.7	6.75, 22.0	**< 0.001**	4.67	2.23, 9.78	**< 0.001**
Respiratory rate						
10–29	—	—		—	—	
>29	2.11	1.25, 3.37	**0.003**	1.24	0.73, 2.10	0.4
6–9[2]	0.00	0.00, 17.9	0.97	-	-	-
1–5	1.12	0.06, 5.58	0.91	0.57	0.06, 5.21	0.6
0[2]	-	-	-	-	-	-
Missing	1.49	0.80, 2.56	0.18	1.00	0.40, 2.48	> 0.9
Systolic blood pressure						
>89	—	—		—	—	
76–89	2.40	1.10, 4.62	**0.016**	1.26	0.59, 2.68	0.5
50–75	4.05	1.62, 8.82	**0.001**	1.95	0.77, 4.95	0.2
1-49[2]	-	-	-	-	-	-
0[2]	-	-	-	-	-	-
Missing[2]	-	-	-	-	-	-
Glasgow Coma Scale						
13–15	—	—		—	—	
9–12	1.77	1.06, 2.78	**0.020**	0.92	0.54, 1.56	0.8
3–8	1.45	0.86, 2.29	0.14	0.76	0.39, 1.47	0.4
Missing	1.21	0.61, 2.15	0.56	0.39	0.15, 1.05	0.063
Working hours						
Yes	—	—		—	—	
No	1.04	0.82, 1.33	0.73	1.05	0.81, 1.35	0.7
Weekend						
Yes	—	—		—	—	
No	1.05	0.82, 1.35	0.73	1.07	0.82, 1.40	0.6
Injury Severity Score						
Mild < 9	—	—		—	—	
Moderate 9–15	3.32	2.32, 4.80	**< 0.001**	2.03	1.36, 3.03	**< 0.001**
Severe 16–25	9.71	6.83, 14.0	**< 0.001**	5.15	3.39, 7.82	**< 0.001**
Profound > 25	9.51	6.53, 14.0	**< 0.001**	5.54	3.43, 8.96	**< 0.001**
Time to first CT						
0–30	—	—		—	—	
No CT	0.95	0.59, 1.47	0.81	0.81	0.50, 1.32	0.4

Table 3 (continued)

	Unadjusted			Adjusted		
Characteristic	OR[1]	95% CI[1]	p-value	OR[1]	95% CI[1]	p-value
31–60	*1.57*	*1.16, 2.13*	***0.003***	*1.53*	*1.11, 2.10*	***0.009***
61–90	*1.46*	*0.98, 2.13*	*0.057*	*2.44*	*1.60, 3.72*	***< 0.001***
>90	*1.37*	*0.98, 1.92*	*0.065*	*1.60*	*1.11, 2.31*	***0.012***
Survival after 30 days						
Alive	*——*	*——*		*——*	*——*	
Dead	*1.31*	*0.74, 2.18*	*0.32*	*0.66*	*0.36, 1.20*	*0.2*

[1] *OR = Odds Ratio, CI = Confidence Interval*

[2] *Not enough observations in this group to allow one or several of its coefficients and CIs to be estimated*

Data availability
The data that support the findings of this study are available following the approval of a project suggesting using the data by the Swedish Ethical Review Authority and the appropriate bodies at the Karolinska University Hospital. More information is available on request from the corresponding author, H. Albaaj. The data are not publicly available due to containing information that could compromise the privacy of research participants.

Declarations

Ethics approval and consent to participate
The study was approved by the Swedish Ethical Review Authority, approval numbers 2021–02541 and 2021–03531.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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