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Study Program in Medicine KI
Degree project 30 credits
Fall 2024

Association between level of hospital care and opportunities for improvement in adult trauma patients

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Associationen mellan vårdnivå och förbättringsfaktorer hos vuxna traumapatienter

Bakgrund: Trauma har en stor inverkan på människors mortalitet och morbiditet globalt. För att förbättra vården av traumapatienter bedrivs det studier på traumaregister. I traumaregister loggas patientfaktorer, exempelvis förbättringsfaktorer (OFI) vilka är faktorer som hade varit möjliga att förhindra och som påverkar mortalitet och morbiditet negativt. Studier visar att antalet OFI ofta skiljer sig över olika vårdnivåer, dock finns det få studier som systematiskt undersöker denna skillnad. Vårdnivå kan delas in i fem nivåer, akutmottagning, vårdavdelning, operationssalen, högre vårdavdelningen och intensivvårdsavdelningen. *Syfte:* Målet med denna studie är att bedöma associationen mellan vårdnivå och patientfaktorer med OFI och kategori av OFI hos traumapatienter. *Material och metod:* Detta var en kohortstudie, baserad på data från Karolinska sjukhusets traumapatientregister. Logistisk regression har använts för att fastställa korrelationen mellan OFI och vårdnivå. För att fastställa korrelationen mellan typ av OFI och vårdnivå har en multinominell logistisk regression används. *Resultat:* Totalt inkluderades 6584 patienter och 395 incidenter av OFI. Åldersintervallet var 15–100 år med en median på 42. 4488 män och 2096 kvinnor inkluderades. Samtliga högre vårdnivåer var signifikant kopplade till OFI, medan akutmottagningen var negativt signifikant kopplat till OFI. Alla högre vårdnivåer hade en korrelation med OFI "otillräckliga resurser". Operationssalen och högre vårdavdelningen hade en korrelation med OFI "otillräckliga protokoll". Operationssalen och intensivvårdsavdelningen hade en korrelation med OFI "förseningar till behandling". *Konklusion:* De tre högsta vårdnivåerna hade en stark association med förekomst av OFI samt med flera kategorier av OFI. Få patientfaktorer var tydligt kopplade till OFI.

Association between level of hospital care and opportunities for improvement in adult trauma patients

Background: Trauma significantly impacts mortality and morbidity worldwide. To improve the care of trauma patients, studies are conducted on trauma registries. Trauma registries track patient factors, such as opportunities for improvement (OFI), which are preventable factors that negatively affect mortality and morbidity. Studies show OFI frequencies vary by level of care, but few systematically investigate this difference. Care levels include the emergency department (ED), general ward, operative theatre (OT), high-dependency unit (HDU), and intensive care unit (ICU). *Aims:* The aim of this study is to determine the association between level of care and patient factors with OFI and category of OFI in trauma patients. *Material and Method:* This was a cohort study made using the Karolinska Hospital trauma registry. Logistic regression assessed the correlation between OFI and care level, while multinomial logistic regression examined the association between category of OFI and care level. *Results:* The study included 6584 patients (4488 men, 2096 women). Ages ranged between 15-100 years with a median age of 42. A total of 395 OFI were identified. All higher levels of care were significantly associated with OFI, while the ED had a negative association. All higher levels of care had a correlation with OFI "inadequate resources". OT and HDU correlated with OFI "inadequate protocols". OT and ICU were correlated with OFI "delays to treatment." *Conclusion:* The three highest levels of care had a strong association with the occurrence of OFI and with several categories of OFI. Few patient factors were clearly linked to OFI.

Keywords: trauma, registry, level of care, opportunities for improvement, mortality

Abbreviations

ATLS – Advanced trauma life support

ED – Emergency department

GCS – Glasgow coma scale

GW – General ward

HDU – High dependency unit/Intermediate care unit

ICU – Intensive care unit

IQR – Interquartile range

ISS – Injury severity score

OFI - Opportunities for improvement

OT – Operative theatre

SweTrau – Swedish trauma registry

Introduction

Trauma, globally and in Sweden

Trauma is an injury due to accident or violence, often happening suddenly (1). Trauma is a global issue affecting millions of people every year worldwide. The exact numbers differ due to different methods of gathering data, and data availability. Worldwide, somewhere between 4-6 million people die every year due to trauma, around 40 million get permanently injured and 100 million get temporarily injured each year (2). In Sweden, 5221 people died due to an external cause of death in 2023 (3). Trauma is commonly divided into two types, blunt force and penetrating force. A patient in a trauma setting may have both types of injuries.

The level of care a trauma patient receives can differ between hospitals, regions and countries. The level of care can differ according to severity of injury, but also according to local regulations, space and economical concerns. In order to locate bleeding imaging modalities such as the x-ray, bedside ultrasound and CT-scan are commonly used in a trauma setting (4). Trauma care is ideally carried out by a trained team, and in accordance with known protocols and routines. One commonly used concept is the Advanced trauma life support (ATLS), which is a protocol governing how to initially assess and treat a trauma patient (5).

Using the American Trauma Society template (6) trauma centres are divided into levels 1-5, with level one providing the highest quality of care. A level one trauma centre has 24-hour access to radiology and several different medical and surgical specialists. A level one trauma centre must also continuously work with trauma improvement programs, as well as education of trauma care personnel.

Opportunities for improvement

Opportunities for improvement (OFI) can be defined as “preventable factors affecting morbidity and mortality”. Examples of such factors are the following: “clinical judgement errors, delays in treatment or diagnosis, missed diagnoses, technical errors, preventable deaths and other errors” (7). OFI or OFI-like parameters are commonly logged in trauma registries. Many level one trauma centres have their own trauma registry to improve and evaluate quality of care. Trauma registries contain information about injuries, care and outcome of trauma patients (8). The registries can then be analysed, and the result can be used to improve trauma care. OFI-like parameters can be variables such as adverse events, defined as “a harmful and negative outcome which happens when a patient has been provided with medical care” (9).

Adverse events are a commonly used parameter in various studies, but the exact definition can vary some. This makes creating a standardised study looking at similar patient data across different populations and registries hard. Usually, adverse events or similar variables are logged in a trauma registry using certain decided parameters, such as patient death within thirty days. They are also often discussed and decided on during medical multidisciplinary conferences.

Levels of care and opportunities for improvement

Level of care can be summarised according to five categories. In order of most care to least care is “emergency department, general ward, operating theatre, high dependency unit and critical care unit”. These are based on the Utstein template (10), a template used in trauma registries for reporting several trauma care variables. Depending on the severity of the injury each patient supposedly ends up in a higher care level. A higher care level equals more doctors, nurses and staff, as well as access to more complex machinery. However, it also equals a higher cost, and a larger drain of resources.

There are several studies on OFI or OFI-like factors in the emergency room and operative theatre, but not many in the general ward and in the high dependency ward. This makes it hard to generalize about specific OFI at these levels of care according to previous articles. There are also few studies on OFI or OFI-like variables in a trauma setting.

Emergency ward and diagnostic error

In a systematic review published in 2022 (11) 5.7% of patients had experienced at least one diagnostic error. This resulted in harm becoming 2% of patients and death in about 0.2%. These percentages are low, but due to the amount of traffic emergency wards receive – about 130 million patients every year in the US, this resulted in 7 million patients being misdiagnosed, harm becoming 2.5 million patients and 350 000 patients dying. Overall in a hospital setting, around 5%-10% of autopsied patients show signs of misdiagnosis being a contributing factor for the patient death (12). A study of 300 000 new York hospital cases found that 14% of errors were diagnostic in nature (13).

Operative theatre

Adverse events due to surgery was deemed the highest risk of adverse events in a hospital setting according to one paper (14) in which 66% of adverse events happened in a surgical setting. The article discusses that around 50% of these adverse events were preventable. In a systematic review containing 16424 surgical patients, 14.4% of patients experienced adverse events and 50% of these were deemed avoidable (15).

Intensive care unit

In a study from 2005, 50 errors involving 32 patients were made by doctors in an ICU setting (16). These errors resulted in a higher mortality rate (38% vs 9%). The errors were categorised as human failures in 73% of cases, and as avoidable in 92%. In a Swedish study involving 128 patients where the patients had died following or during ICU care, 22 patients having suffered avoidable adverse events were identified (17).

Area of further research

More studies related to doctor error, adverse events and OFI have been conducted in the emergency ward setting, the operating theatre and the intensive care unit compared to the general ward and the high-dependency unit. This might point to the fact that there may be possible to affect a larger number of opportunities for improvement in these less studied cohorts.

There have been some studies previously regarding OFI and OFI-like factors in a trauma setting, but most studies focus on OFI-like factors while not being specific to trauma. There are also very few studies with the direct focus on how OFI relates to care level. Previous studies show that there exists a connection between OFI and level of care (18), but this connection has not been examined directly. There exist studies on specific OFI or OFI-like factors in specific levels of care, but there have not been many systematic approaches made where the same measure for OFI is compared across different care levels.

Aim

The aim of this study was to determine the association between the highest level of in-hospital care and OFI and category of OFI, as well as how patient factors are associated with these opportunities at each level.

Materials and methods

Study design

This was a registry-based cohort study.

Setting

This study was based on data collected at Karolinska University Hospital trauma center, a level I trauma center (6). Opportunities for improvement are since 2017 in Karolinska Hospital measured by a specialised nurse, who reviews all trauma patient cases and flags cases where OFI might be found (18). The cases flagged then get reviewed at a deeper level by another specialised nurse, and the cases where OFI might be found gets reviewed at a multidisciplinary

conference, where the final decision on the presence of OFI is made by consensus. All patients dying due to trauma are also discussed in a conference where OFI is discussed. Before 2017 OFI was decided by a small group of clinicians by consensus.

In this paper we used the trauma care quality database and trauma registry from Karolinska University hospital. The data available in the trauma registry includes 14000 trauma patients from the years 2012-2023. The data from the trauma care quality database is a subset of the same data containing around 8000 patients where opportunities for improvement have also been registered. The data contains information according to the Utstein template, which includes factors such as Glasgow coma scale (GCS), systolic blood pressure and respiratory rate (10).

Participants

The patients included were all above the age of 15, with an injury severity score (ISS) greater than 9 or patients with a trauma team activation upon hospital arrival. Excluded patients were younger than 15 or dead upon arrival.

Variables

All variables were taken from the data registered in the Karolinska Hospital trauma registry. The following patient factors were included in this study as continuous variables, presented with mean and interquartile range: patient age, Glasgow coma scale at arrival to hospital, respiratory rate at arrival, injury severity score and systolic blood pressure at arrival to the hospital. The following patient factors were included in the study as categorical variables, presented with frequency and percentage: patient sex, injury mechanism, ASA score preinjury, 30-day survival, highest level of in-hospital care, OFI, and category of OFI. OFI and category of OFI were the outcome variables in two separate analyses, while the rest of the variables were used as predictors. Highest level of in-hospital care was used as a predictor in both unadjusted and adjusted analyses, while the other variables were only used in the adjusted analyses. 30-day survival was not used in the adjusted analysis on category of OFI, due to there being no dead patients having had both 30-day survival and category of OFI logged.

Categorization

Of the continuous variables, patient age included all ages present in the register, which were found in a range of 15-100. Patients younger than 15 were excluded from the study. Glasgow coma scale at arrival to the hospital could be logged in a range of 3-15, and were in accordance with known guidelines on GCS (10,19). Patients were registered in the entire 3-15 range but had a median of 15. Respiratory rate at arrival to the hospital was logged in the range of 60-0,

with a median of 18. Injury severity score could be logged from 0-75 and were present in the sample in the full range, with a median of 9. Systolic blood pressure at arrival to the hospital was logged in the range between 285-0 with a median of 135 and was measured in millimetres of mercury.

Of the categorical variables, OFI had two categories: presence of OFI and absence of OFI. Patient sex had two categories, male and female. ASA score preinjury was divided into four categories in accordance to the American society of anaesthesiologists (20). No patient with ASA-score higher than four was found in the patient data. Injury mechanism was divided into the following twelve categories in accordance to the Swedish trauma registry (SweTrau) database (19). It is presented here in simplified manner: 1. Vehicle accident, 2. Motorcycle accident, 3. Bicycle accident, 4. Pedestrian accident, 5. Accident other vehicle, 6. Gunshot, 7. Knife, 8. Blunt object, 9. Fall in the same elevation, 10. Fall from other elevation, 11. Explosion injury, 12. Other injury. Category of OFI were logged and divided into the following seven categories: clinical judgement error, delay in treatment, documentation issues, inadequate protocols, inadequate resources, missed diagnosis and other errors. The levels of care are categorized according to the Utsein definition (10), from lowest to highest level of care: emergency department (ED), general ward (GW), operative theatre (OT), high-dependency unit (HDU) and intensive care unit (ICU). 30-day survival had two categories, alive after 30 days and dead after 30 days.

Outcome measures and exposure

The primary outcome of this study was the presence of opportunity for improvement, measured as a binary variable. The secondary outcome was the presence of category of OFI, each measured as a binary variable. The primary exposure variable in both outcomes were the highest level of in hospital care a patient received.

Statistical analysis

Unadjusted and adjusted logistic regression were used to determine the associations between level of care and opportunities for improvement. To characterise the category of OFI and connect it to the level of care, a multinomial unadjusted and adjusted regression were used. The general ward was considered the baseline for comparison. Categorical data are presented with frequency and percentages, while continuous data are presented with the mean and interquartile range. Synthetic data was used when developing the code required to extract data. When this code was deemed functional, it was implemented on the real data. This was done to decrease

risk of bias. A 5% significance level and 95% confidence levels were used in this paper. R was used for statistical analysis.

Ethical permit and consideration

This study was a retrospective observational cohort study, which means that there was no intervention done with risk to the patients included.

Having patients' personal data included in a register and such as the one used in this study and analysed is a breach of privacy and integrity. Therefore, great care has been taken to protect the data and to keep the patients from being identified. Patients included in this study have had their personal identification number replaced with a study number before the data reached the author of this paper. This is done to hinder the possibility of identifying specific patients. The data is stored and accessed through a password protected secured server which is only accessible to a small number of scientists. Only variables deemed potentially important to the care of patients have been logged in the trauma registry. Still, the data used in this project contains a lot of patient information. Putting together the different variables used may make it possible to identify a specific patient, which is the reason that all information is presented in group form where no specific patient can be identified.

Patients included in the trauma registry have not needed to consent to be included in the registry. However, all included patients have been informed of their participation orally and in written and have had the opportunity to opt out of the registry.

The trauma registry used in this study is run by employees of the hospital evaluated by the registry. This means that there is the possibility that information in the registry that puts the hospital in a bad light may have been excluded from the registry, either consciously or unconsciously. To minimize the risk of this the group working with the trauma registry work independently of the rest of the hospital. Internal regulations are also in place, such as the OFI variable being examined in connection with all trauma patients who die in the hospital.

The purpose of this study is to improve the quality of care for trauma patients. There are no apparent risks that this study may be used for malicious use. It is possible that this study may be used for future commercial use by a private health centre. This would most likely be to the benefit of the patients in this health centre and is therefore not a valid reason for not publishing this study.

This study is aimed at improving the care of trauma patients, this both locally at the Karolinska Hospital in Sweden and globally through a greater understanding of where factors negatively affecting patient mortality and morbidity may appear. This study is also aimed at controlling the quality of care of trauma patients locally at the Karolinska hospital in Sweden. In conclusion, the benefit of this study greatly outweighs the drawbacks.

Ethical permission has been obtained for this study by the Swedish ethical review authority. Ethical permit: 2021-02541, 2021-03531 and 2023-02975-02.

Results

Population outcomes

Figure 1 shows the population outcome. A total of 14022 patients were included in the registry. Out of these, 5710 patients were excluded due to not having an OFI variable recorded. 1728 were excluded due to missing other variables, making the studied population 6584 patients.

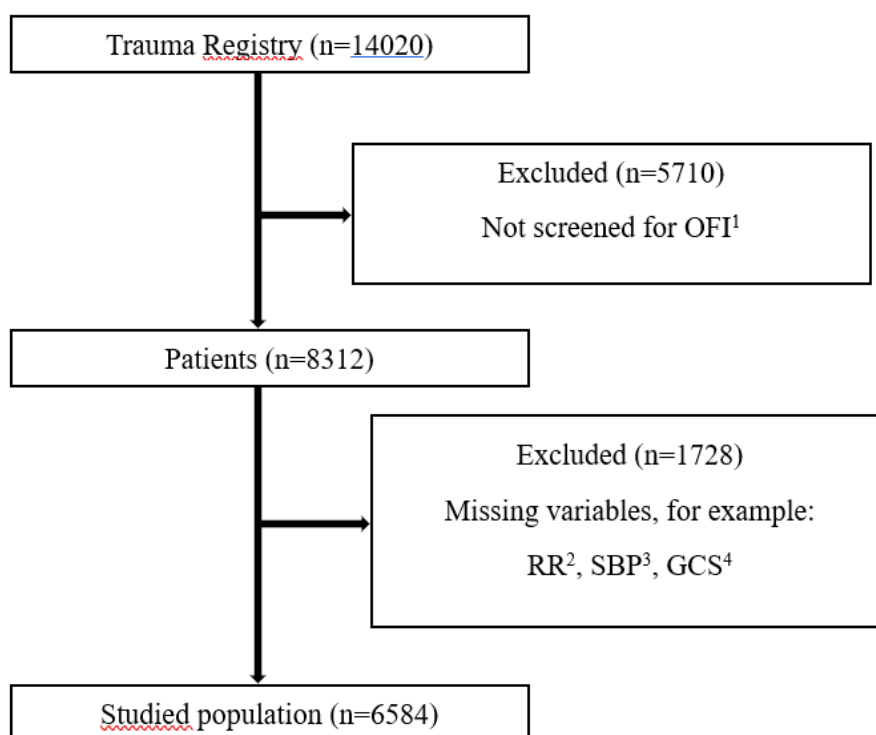


Figure 1. Flow chart of studied population

¹ OFI = Opportunities for improvement, ² RR = Respiratory rate, ³ SBP = Systolic blood pressure, ⁴ GCS = Glasgow coma scale.

Table 1 shows patient characteristics. Of the studied population, a total of 395 (6%) patients had experienced an OFI, while 6189 (94%) patients had not. 4488 (68%) men were included in

the study, of which 277 (70% of OFI) had experienced an OFI. 2096 (32%) women were included, of which 118 (30%) had experienced an OFI. The median age (IQR) of the patients included in the study was 42 (26, 61). The median age (IQR) for patients experiencing an OFI was higher at 49 (30, 68). The most common injury mechanism included in the study was injury mechanism 10, *fall from different level* (1490 patients, 23% of population). The most common ASA score among patients included in the study was 1 (3805 patients, 58% of population). Among the patients experiencing an OFI, ASA 1 was also the most common one (203 patients, 51%). The median injury severity score in the studied population was 8 (IQR 1, 14). In the group having experienced an OFI, the median was higher at 17 (IQR 10, 22).

The high-dependency unit was the least common highest level of care, with 332 patients (5.0%), while the general ward was the most common highest level of care, with 2804 (43%) patients. It was more common for the patients with a higher level of care (OT, HDU and ICU) to experience OFI: 31% of patients experienced their OFI with their highest level of care being the OT while only 21% of all patients had the OT as their highest level of care. Among patients with HDU as the highest level of care 11% of the patients experienced OFI versus 5.0% in the total sample, and in the group with the ICU as their highest level of care 24% of the patients had an OFI compared to 13% of the population. Only 4.3% of patients with OFI had the ED as their highest level of care, compared to 19% of the population. 30% of patients who had the general ward as their highest level of care had OFI compared to 43% of the total population. There was no large difference in 30-day survival between the patients experiencing an OFI versus the patients not experiencing an OFI, with 219 (3.5%) of the deceased patients in the no OFI group, and 15 (3.8%) of the deceased patients in the OFI group.

A total of 379 instances of category of OFI had been logged. OFI had in 16 instances been logged without including category of OFI. The most common reason a patient had experienced an OFI was because of clinical judgment errors (150 incidents or 38% of OFI), the second most common was inadequate resources (88 incidents or 23%).

Table 1. Patient data characteristics, vital signs, highest level of care, 30-day survival and OFI

Table of patient data. For the continuous variables, the two numbers in parentheses are the interquartile range (IQR). Injury mechanism is simplified. Most variables can be found in the SweTrau database (19).

Characteristic	Overall N = 6,584 ¹	No OFI ¹ N = 6,189 ¹	OFI N = 395 ¹
Age in years	42 (26, 61)	42 (26, 60)	49 (30, 68)
Patient sex			
Male	4,488 (68%)	4,211 (68%)	277 (70%)
Female	2,096 (32%)	1,978 (32%)	118 (30%)

Injury mechanism			
1. Vehicle accident	973 (15%)	923 (15%)	50 (13%)
2. Motorcycle accident	535 (8.1%)	491 (7.9%)	44 (11%)
3. Bicycle accident	566 (8.6%)	532 (8.6%)	34 (8.6%)
4. Pedestrian accident	231 (3.5%)	215 (3.5%)	16 (4.1%)
5. Accident other vehicle	69 (1.0%)	64 (1.0%)	5 (1.3%)
6. Gunshot	218 (3.3%)	204 (3.3%)	14 (3.5%)
7. Knife	783 (12%)	752 (12%)	31 (7.8%)
8. Blunt object	672 (10%)	641 (10%)	31 (7.8%)
9. Fall in the same elevation	965 (15%)	905 (15%)	60 (15%)
10. Fall from other elevation	1,490 (23%)	1,385 (22%)	105 (27%)
11. Explosion injury	24 (0.4%)	23 (0.4%)	1 (0.3%)
12. Other injury	58 (0.9%)	54 (0.9%)	4 (1.0%)
ASA-score preinjury			
1	3,805 (58%)	3,602 (58%)	203 (51%)
2	1,633 (25%)	1,530 (25%)	103 (26%)
3	1,083 (16%)	996 (16%)	87 (22%)
4	63 (1.0%)	61 (1.0%)	2 (0.5%)
GCS² at arrival	15.00 (15.00, 15.00)	15.00 (15.00, 15.00)	15.00 (14.00, 15.00)
Blood pressure at arrival	137 (123, 151)	137 (123, 151)	137 (120, 153)
Respiratory rate at arrival	18.0 (16.0, 20.0)	18.0 (16.0, 20.0)	18.0 (16.0, 20.0)
Injury severity score	8 (1, 14)	5 (1, 14)	17 (10, 22)
Highest level of hospital care			
General Ward	2,804 (43%)	2,686 (43%)	118 (30%)
Emergency Care	1,269 (19%)	1,252 (20%)	17 (4.3%)
Operation Theater	1,356 (21%)	1,234 (20%)	122 (31%)
Intermediate Care	332 (5.0%)	289 (4.7%)	43 (11%)
ICU ³	823 (13%)	728 (12%)	95 (24%)
30 day survival			
Dead	234 (3.6%)	219 (3.5%)	15 (3.8%)
Alive	6,350 (96%)	5,970 (96%)	380 (96%)
Category of OFI			
No category logged/No OFI	6,205 (94%)	6,189 (100%)	16 (4.1%)
Clinical judgement error	150 (2.3%)	0 (0%)	150 (38%)
Delay in treatment	53 (0.8%)	0 (0%)	53 (13%)
Documentation Issues	10 (0.2%)	0 (0%)	10 (2.5%)
Inadequate protocols	18 (0.3%)	0 (0%)	18 (4.6%)
Inadequate resources	88 (1.3%)	0 (0%)	88 (22%)
Missed diagnosis	57 (0.9%)	0 (0%)	57 (14%)
Other errors	3 (<0.1%)	0 (0%)	3 (0.8%)

¹ OFI = Opportunities for improvement, ² GCS = Glasgow coma scale, ³ ICU = Intensive care unit.

Association between factors and OFI

Table 2 shows the unadjusted logistic regression, with OFI as outcome and highest level of hospital care as the predictor. In the unadjusted analysis, the highest level of care being the operative theatre (OR 2.40, CI 1.86-3.09, p-value <0.001), the HDU (OR 3.55, CI 2.49-4.99, p-value <0.001) and the ICU (OR 3.10, CI, 2.39-4.01, p-value <0.001) were significantly

associated with OFI. Conversely, only receiving care in the emergency department was significantly negatively associated with OFI (OR 0.38, CI 0.23-0.59, p-value <0.001).

Table 2. Logistic regression

Outcome is opportunities for improvement, predictor is highest level of hospital care. **Bold** p-value means the association is statistically significant.

Characteristic	OR ¹	95% CI ²	p-value
Highest level of hospital care			
General Ward	—	—	
Emergency Care	0.38	0.23, 0.59	<0.001
Operation Theater	2.40	1.86, 3.09	<0.001
Intermediate Care	3.55	2.49, 4.99	<0.001
ICU ³	3.10	2.39, 4.01	<0.001

¹ OR = Odds Ratio, ² CI = Confidence Interval, ³ ICU = Intensive care unit

Table 3 shows the adjusted logistic regression, with OFI as the outcome and highest level of care and patient factors as the predictor. In the adjusted logistic regression, highest level of care being the OT (OR 1.68, CI 1.28-2.22, p-value <0.001), HDU (OR 2.26, CI 1.51-3.31, p-value <0.001), and ICU (OR 1.56, CI 1.08-2.23, p-value 0.016) were significantly associated with OFI. ED (OR 0.42, CI 0.24-0.69, p-value 0.001) was also significantly negatively associated with OFI, meaning that fewer patients with the ED as their highest level of care experienced an OFI. Of the patient factors ISS (OR 1.06, CI 1.04-1.07, p-value <0.001) was significantly associated with OFI, as well as 30-day survival (OR 2.26, CI 1.25-4.35, p-value <0.001), where a higher 30-day survival had a clear correlation with more OFI.

Table 3. Adjusted logistic regression

Outcome is opportunities for improvement, predictor is highest level of hospital care, age in years, patient sex, ASA-score preinjury, GCS at arrival, blood pressure at arrival, respiratory rate at arrival, injury mechanism, injury severity score and 30-day survival. **Bold** p-value means the association is statistically significant. Injury mechanism is simplified. Most variables can be found in the SweTrau database (19).

Characteristic	OR ¹	95% CI ²	p-value
Highest level of hospital care			
General Ward	—	—	
Emergency Care	0.42	0.24, 0.69	0.001
Operation Theater	1.68	1.28, 2.22	<0.001
Intermediate Care	2.26	1.51, 3.31	<0.001
ICU ³	1.56	1.08, 2.23	0.016
Age in years	1.00	1.00, 1.01	0.15
Patient sex			
Male	—	—	
Female	1.03	0.80, 1.30	0.8
ASA-score preinjury			

1	—	—	
2	0.97	0.74, 1.26	0.8
3	1.14	0.81, 1.60	0.4
4	0.59	0.09, 2.02	0.5
GCS⁴ at arrival	1.04	0.99, 1.10	0.2
Blood pressure at arrival	1.00	1.00, 1.01	0.6
Respiratory rate at arrival	1.00	0.98, 1.02	0.8
Injury mechanism			
1. Vehicle accident	—	—	
2. Motorcycle accident	1.15	0.74, 1.78	0.5
3. Bicycle accident	0.95	0.59, 1.50	0.8
4. Pedestrian accident	0.90	0.48, 1.63	0.7
5. Accident other vehicle	0.90	0.30, 2.22	0.8
6. Gunshot	0.89	0.45, 1.65	0.7
7. Knife	0.70	0.43, 1.12	0.14
8. Blunt object	0.75	0.46, 1.21	0.2
9. Fall in the same elevation	0.86	0.56, 1.33	0.5
10. Fall from other elevation	0.91	0.63, 1.31	0.6
11. Explosion injury	0.63	0.03, 3.26	0.7
12. Other injury	0.93	0.27, 2.46	0.9
ISS⁵	1.06	1.04, 1.07	<0.001
30-day survival			
Dead	—	—	
Alive	2.26	1.25, 4.35	0.010

¹OR = Odds Ratio, ²CI = Confidence Interval, ³ICU = Intensive care unit, ⁴GCS = Glasgow coma scale,

⁵ISS = Injury severity score.

Associations between factors and categories of OFI

Table 4 shows the unadjusted multivariable logistic regression. Category of OFI is the outcome, and highest level of hospital care is the predictor. Table 5 shows the adjusted multivariable logistic regression. Category of OFI is the outcome, highest level of care and patient factors are the predictor.

Clinical judgement error

In the unadjusted multinomial regression analysis, OT (OR 1.92, CI 1.30-2.83, p-value 0.001), HDU (OR 3.49, CI 2.10-5.79, p-value <0.001) and ICU (OR 2.06, CI 1.36-3.13, P-value <0.001) were significantly associated with the OFI category clinical judgement error. ED (OR 0.04, CI 0.01-0.029, p-value 0.001) was significantly negatively associated with clinical judgement error.

In the adjusted analysis, HDU (OR 2.04, CI 1.17-3.58, p-value 0.006) was significantly associated with clinical judgement error. ED (OR 0.06, CI 0.01-0.44, p-value 0.006) was significantly negatively associated with clinical judgement error. Statistical significance was not achieved in the OT or ICU. Patient factors with more than one patient associated with

clinical judgement error in the adjusted analysis were ISS (OR 1.07, CI 1.05-1.09, p-value <0.001).

Delay in treatment

In the unadjusted analysis OT (OR 4.95, CI 2.35-10.4, p-value <0.001) and ICU (OR 5.82, CI 2.72-12.5, p-value <0.001) were significantly associated with OFI delay in treatment. In the adjusted analysis, OT (OR 4.12, CI 1.89-9.01, p-value <0.001) and ICU (OR 3.15, CI 1.17-8.45, p-value 0.023) were significantly associated with delay in treatment. Of the patient factors, only injury mechanism 5, *Injury from other type of vehicle* (OR 5.69, CI 1.25-25.9, p-value 0.025) achieved statistical significance and had more than zero patients.

Documentation issues

No level of care nor were significantly associated with documentation issues in the unadjusted analysis. In the adjusted analysis, no care level with more than zero patients achieved statistical significance.

Inadequate protocols

In the unadjusted analysis, OT (OR 10.8, CI 2.35-49.1, p-value 0.002), HDU (OR 13.1, CI 2.18-78.5, p-value 0.005), and ICU (OR 10.2, CI 2.11-49.1, p-value 0.004) were significantly associated with the OFI inadequate protocols. In the adjusted analysis OT (OR 6.76, CI 1.48-30.8, p-value 0.014) and HDU (OR 7.20, CI 1.16-44.5, p-value 0.034) were significantly associated with inadequate protocols. Of the patient factors, GCS at arrival to hospital (OR 1.67, CI 1.32-2.27, p-value <0.001) and ISS (OR 1.07, CI 1.02-1.12, p-value 0.006) were significantly associated.

Inadequate resources

In the unadjusted analysis, OT (OR 3.51, CI 1.98-6.23, p-value <0.001), HDU (OR 8.25, CI 4.29-15.9, p-value <0.001) and ICU (OR 4.59, CI 2.57-8.20, p-value <0.001) were significantly associated with OFI inadequate resources. In the adjusted analysis OT (OR 2.20, CI 1.19-4.07, p-value 0.012), HDU (OR 5.28, CI 2.53-11.0, p-value <0.001) and ICU (OR 3.05, CI 1.46-6.35, p-value 0.003) were also significantly associated with inadequate resources. The only patient factor with more than zero patients significantly associated was ISS (OR 1.05, CI 1.02-1.07, p-value <0.001)

Missed diagnosis

No level of care was significantly associated with missed diagnosis. Of the patient factors with more than zero patients significantly associated were GCS at arrival to hospital (OR 1.79, CI 1.05-3.05, p-value 0.033), injury mechanism 2, *Motorcycle accident* (OR 3.61, CI 1.19-8.09, p-value 0.021) and injury mechanism 3, *Bicycle accident* (OR 3.10, CI 1.19-8.09, p-value 0.021) and ISS (OR 1.04, CI 1.00-1.08, p-value 0.036).

Other errors

No level of care or patient factors with more than zero patients were significantly associated with other errors, both in the unadjusted and the adjusted analysis.

Table 4. Multinomial Logistic Regression Results

Category of opportunity for improvement is set as outcome. Highest level of hospital care as predictor. **Bold** p-value means the association is statistically significant.

Opportunity for improvement	Event Rate	OR ¹	95% CI ²	p-value
Clinical judgement error				
General Ward	55 / 3,063 (1.8%)	—	—	
Emergency Care	1 / 1,358 (0.07%)	0.04	0.01, 0.29	0.001
Operation Theater	49 / 1,503 (3.3%)	1.92	1.30, 2.83	0.001
Intermediate Care	22 / 387 (5.7%)	3.49	2.10, 5.79	<0.001
ICU ³	39 / 1,125 (3.5%)	2.06	1.36, 3.13	<0.001
Delay in treatment				
General Ward	10 / 3,063 (0.33%)	—	—	
Emergency Care	2 / 1,358 (0.15%)	0.44	0.10, 2.01	0.3
Operation Theater	23 / 1,503 (1.5%)	4.95	2.35, 10.4	<0.001
Intermediate Care	3 / 387 (0.78%)	2.61	0.72, 9.54	0.15
ICU ³	20 / 1,125 (1.8%)	5.82	2.72, 12.5	<0.001
Documentation Issues				
General Ward	6 / 3,063 (0.20%)	—	—	
Emergency Care	0 / 1,358 (0.00%)	0.00	0.00, Inf	0.9
Operation Theater	5 / 1,503 (0.33%)	1.79	0.55, 5.89	0.3
Intermediate Care	0 / 387 (0.00%)	0.00	0.00, 1,946,671,436,516,605,440	0.8
ICU ³	3 / 1,125 (0.27%)	1.46	0.36, 5.83	0.6
Inadequate protocols				
General Ward	2 / 3,063 (0.07%)	—	—	
Emergency Care	0 / 1,358 (0.00%)	0.00	0.00, 0.00	<0.001
Operation Theater	10 / 1,503 (0.67%)	10.8	2.35, 49.1	0.002
Intermediate Care	3 / 387 (0.78%)	13.1	2.18, 78.5	0.005
ICU ³	7 / 1,125 (0.62%)	10.2	2.11, 49.1	0.004
Inadequate resources				
General Ward	19 / 3,063 (0.62%)	—	—	
Emergency Care	4 / 1,358 (0.29%)	0.46	0.16, 1.36	0.2
Operation Theater	31 / 1,503 (2.1%)	3.51	1.98, 6.23	<0.001
Intermediate Care	18 / 387 (4.7%)	8.25	4.29, 15.9	<0.001
ICU ³	30 / 1,125 (2.7%)	4.59	2.57, 8.20	<0.001
Missed diagnosis				

General Ward	25 / 3,063 (0.82%)	—	—	
Emergency Care	11 / 1,358 (0.81%)	0.97	0.47, 1.97	0.9
Operation Theater	16 / 1,503 (1.1%)	1.38	0.73, 2.59	0.3
Intermediate Care	3 / 387 (0.78%)	1.05	0.31, 3.48	0.9
ICU ³	11 / 1,125 (0.98%)	1.28	0.63, 2.61	0.5
Other errors				
General Ward	1 / 3,063 (0.03%)	—	—	
Emergency Care	0 / 1,358 (0.00%)	0.00	0.00, 0.00	<0.001
Operation Theater	0 / 1,503 (0.00%)	0.00	0.00, 0.00	<0.001
Intermediate Care	0 / 387 (0.00%)	0.02	0.00, 3,880,889,109,061,703	0.8
ICU ³	3 / 1,125 (0.27%)	8.74	0.91, 84.2	0.061

¹OR = Odds Ratio, ²CI = Confidence Interval, ³ICU = Intensive care unit.

Table 5. Multinomial Logistic Regression Results – Adjusted analysis

Outcome is category of opportunity for improvement, predictor is highest level of hospital care, age in years, patient sex, ASA-score preinjury, GCS at arrival, blood pressure at arrival, respiratory rate at arrival, injury mechanism and injury severity score. **Bold** p-value means the association is statistically significant. Injury mechanism is simplified. Most variables can be found in the SweTrau database (19). Category of OFI: clinical judgement error, delay in treatment, documentation issues, inadequate protocols, inadequate resources, missed diagnosis and other errors are subheadings. Statistically significant associations with more than one patient and association between category of OFI and highest level of hospital care can be seen in table 5. For complete table, see appendix 1.

Opportunity for improvement	Event Rate	OR ¹	95% CI ²	p-value
Clinical judgement error				
General Ward	52 / 2,804 (1.9%)	—	—	
Emergency Care	1 / 1,269 (0.08%)	0.06	0.01, 0.44	0.006
Operation Theater	45 / 1,356 (3.3%)	1.34	0.87, 2.06	0.2
Intermediate Care	20 / 332 (6.0%)	2.04	1.17, 3.58	0.012
ICU ³	32 / 823 (3.9%)	0.81	0.46, 1.45	0.5
ISS⁴	379 / 6,584 (5.8%)	1.07	1.05, 1.09	<0.001
Delay in treatment				
General Ward	10 / 2,804 (0.36%)	—	—	
Emergency Care	2 / 1,269 (0.16%)	0.52	0.11, 2.37	0.4
Operation Theater	23 / 1,356 (1.7%)	4.12	1.89, 9.01	<0.001
Intermediate Care	3 / 332 (0.90%)	2.44	0.65, 9.14	0.2
ICU ³	15 / 823 (1.8%)	3.15	1.17, 8.45	0.023
Injury mechanism				
1. Vehicle accident	5 / 973 (0.51%)	—	—	
2. Motorcycle accident	4 / 535 (0.75%)	1.10	0.29, 4.15	0.9
3. Bicycle accident	1 / 566 (0.18%)	0.31	0.04, 2.63	0.3
4. Pedestrian accident	3 / 231 (1.3%)	1.79	0.41, 7.79	0.4
5. Accident other vehicle	3 / 69 (4.3%)	5.69	1.25, 25.9	0.025
6. Gunshot	6 / 218 (2.8%)	3.26	0.94, 11.4	0.064
7. Knife	6 / 783 (0.77%)	1.12	0.33, 3.82	0.9
8. Blunt object	7 / 672 (1.0%)	1.68	0.52, 5.43	0.4
9. Fall in the same elevation	8 / 965 (0.83%)	1.32	0.39, 4.44	0.7
10. Fall from other elevation	10 / 1,490 (0.67%)	0.89	0.30, 2.67	0.8
11. Explosion injury	0 / 24 (0.00%)	0.03	0.03, 0.04	<0.001
12. Other injury	0 / 58 (0.00%)	0.01	0.01, 0.01	<0.001
Documentation Issues				

General Ward	6 / 2,804 (0.21%)	—	—	
Emergency Care	0 / 1,269 (0.00%)	0.00	0.00, 0.00	<0.001
Operation Theater	3 / 1,356 (0.22%)	0.85	0.19, 3.92	0.8
Intermediate Care	0 / 332 (0.00%)	0.01	0.01, 0.01	<0.001
ICU ³	1 / 823 (0.12%)	0.30	0.02, 4.50	0.4
Inadequate protocols				
General Ward	2 / 2,804 (0.07%)	—	—	
Emergency Care	0 / 1,269 (0.00%)	0.01	0.01, 0.01	<0.001
Operation Theater	9 / 1,356 (0.66%)	6.76	1.48, 30.8	0.014
Intermediate Care	3 / 332 (0.90%)	7.20	1.16, 44.5	0.034
ICU ³	4 / 823 (0.49%)	4.50	0.71, 28.4	0.11
Age in years	379 / 6,584 (5.8%)	1.04	1.01, 1.08	0.009
GCS ⁵ at arrival	379 / 6,584 (5.8%)	1.76	1.37, 2.27	<0.001
ISS ⁴	379 / 6,584 (5.8%)	1.07	1.02, 1.12	0.006
Inadequate resources				
General Ward	19 / 2,804 (0.68%)	—	—	
Emergency Care	4 / 1,269 (0.32%)	0.51	0.17, 1.51	0.2
Operation Theater	26 / 1,356 (1.9%)	2.20	1.19, 4.07	0.012
Intermediate Care	14 / 332 (4.2%)	5.28	2.53, 11.0	<0.001
ICU ³	25 / 823 (3.0%)	3.05	1.46, 6.35	0.003
ISS ⁴	379 / 6,584 (5.8%)	1.05	1.02, 1.07	<0.001
Missed diagnosis				
General Ward	23 / 2,804 (0.82%)	—	—	
Emergency Care	10 / 1,269 (0.79%)	1.00	0.45, 2.24	>0.9
Operation Theater	15 / 1,356 (1.1%)	1.15	0.57, 2.31	0.7
Intermediate Care	3 / 332 (0.90%)	1.22	0.35, 4.28	0.8
ICU ³	6 / 823 (0.73%)	1.17	0.39, 3.51	0.8
GCS ⁵ at arrival	379 / 6,584 (5.8%)	1.79	1.05, 3.05	0.033
Injury mechanism				
1. Vehicle accident	7 / 973 (0.72%)	—	—	
2. Motorcycle accident	14 / 535 (2.6%)	3.61	1.40, 9.31	0.008
3. Bicycle accident	12 / 566 (2.1%)	3.10	1.19, 8.09	0.021
4. Pedestrian accident	1 / 231 (0.43%)	0.51	0.06, 4.20	0.5
5. Accident other vehicle	1 / 69 (1.4%)	1.95	0.23, 16.2	0.5
6. Gunshot	0 / 218 (0.00%)	0.00	0.00, 0.00	<0.001
7. Knife	2 / 783 (0.26%)	0.39	0.08, 1.93	0.3
8. Blunt object	5 / 672 (0.74%)	1.13	0.35, 3.65	0.8
9. Fall in the same elevation	3 / 965 (0.31%)	0.47	0.11, 1.94	0.3
10. Fall from other elevation	12 / 1,490 (0.81%)	1.00	0.38, 2.60	>0.9
11. Explosion injury	0 / 24 (0.00%)	0.03	0.03, 0.03	<0.001
12. Other injury	0 / 58 (0.00%)	0.01	0.01, 0.01	<0.001
ISS ⁴	379 / 6,584 (5.8%)	1.04	1.00, 1.08	0.036
Other errors				
General Ward	1 / 2,804 (0.04%)	—	—	
Emergency Care	0 / 1,269 (0.00%)	0.00	0.00, 0.00	<0.001
Operation Theater	0 / 1,356 (0.00%)	0.00	0.00, 0.00	<0.001
Intermediate Care	0 / 332 (0.00%)	0.02	0.02, 0.02	<0.001
ICU ³	2 / 823 (0.24%)	1.74	0.08, 37.6	0.7

¹ OR = Odds Ratio, ² CI = Confidence Interval, ³ ICU = Intensive care unit, ⁴ ISS = Injury severity score,

⁵ GCS = Glasgow coma scale

Discussion

OFI and highest level of care, a summary

The purpose of this study was to determine the association between the highest level of in-hospital care and OFI. The result of both an adjusted and unadjusted regression indicates a positive association between OFI and a patient's highest level of care being the ICU, HDU or the OT. There is a negative association between the ED and OFI, with a patient being less likely to experience OFI when the highest level of care a patient experience is the ED. In general, in the unadjusted analysis all variables indicated stronger associations between level of care and OFI, or in the case of the ED a larger negative correlation compared to the adjusted analysis, showing that the variables adjusted for were correlated with the outcome.

Also done in this study was to determine the association between the highest level of in-hospital care and category of OFI. The result of a multinomial analysis showed that all higher levels of care have a correlation with the category of OFI inadequate resources. Patients with their highest care level being the OT and HDU also correlated to the OFI inadequate protocols, and patients with the highest care level being the OT and ICU also correlated with the OFI delay to treatment. The ED had in general a negative predictive correlation with most categories of OFI, but the few patients with category of OFI logged with the ED as their highest level of care made analysing prone to error.

Category of OFI

Clinical judgement error

In the unadjusted analysis, OT, HDU and ICU were significantly associated with the OFI category *clinical judgement error*. ED was significantly negatively associated with clinical judgement error. In the adjusted analysis, only HDU was significantly positively associated with clinical judgement error while ED was significantly negatively associated. The ED, while also reaching statistical significance, had only one patient which does not make a robust enough result to take away any data from. Of the patient factors, having a higher ISS had a slight association with clinical judgement error. Few previous studies have been done specifically on clinical judgement error regarding trauma patients in the HDU. One previous study showed that patients requiring medium or high-risk emergency surgery had an increase in mortality when they postoperative were placed in the HDU compared to the ICU (21). Being placed in the wrong care level can be considered a type of clinical judgment error, which points to the fact that patients may be placed in the HDU when they should be placed in the ICU based on the severity of their injuries.

Delay in treatment

In the unadjusted and adjusted analyses both OT and ICU were significantly associated with delay in treatment. This points towards the fact that time to surgery may be an important factor when it comes to avoiding OFI in the operative theatre. This is concurrent with a previous study which shows that a delay to treatment often occurs in the operative theatre, and that this leads to adverse events (15). Another study also points toward the fact that a delay to getting to the operative theatre leads to increased mortality (22). The ICU also had a significant association with delay to treatment. It's possible that delay to treatment during a trauma patients care may lead to worse adverse events and eventually a higher risk of a patient ending up in the ICU. However, in that case the HDU should also have a statistically significant association with delay to treatment. Several studies (23, 24) show that a delay to being treated in the ICU leads to worse survival outcomes. It is possible that being delayed to treatment in the ICU have a larger probability of affecting mortality and morbidity compared to being delayed to treatment in the HDU or the general ward. The small sample size may explain the reason why injury mechanism 5, *Injury from other type of vehicle* had a strong association with delay in treatment. There were only three patients having experienced injury mechanism 5.

Documentation issues

No analysis of documentation issues resulted in any statistical significance, most likely due to there only being 14 patients logged as having experienced documentation issues as the reason for their OFI. OFI, being “factors that affect mortality and morbidity”, may not be affected that much by documentation errors, despite there being at least one study showing that documentation errors are prevalent in at least the ED (25). It's reasonable to assume that documentation errors would also be prevalent in the care of trauma patients, which may point towards the fact that documentation error is not a large risk to patient mortality or morbidity in trauma care.

Inadequate protocols

OT and HDU were significantly associated with OFI *inadequate protocols* in both the adjusted and unadjusted analysis. ED was also significantly negatively associated with inadequate protocols, however there being zero patients in the ED makes it hard to draw any large conclusions based on this result. It is possible that the protocols governing the ED are better compared to those in the OT and HDU. Previous studies points toward the fact that inadequate protocols, or a failure to accurately follow adequate protocols, leads to an increased mortality in surgical patients (26), which is in line with the results of this study. Patients with a higher

GCS at arrival to the hospital were also associated with experiencing inadequate protocols. It is possible that the protocols governing unconscious patient may be better compared to conscious patients. There exist several studies on how to handle unconscious patients (27), but few studies comparing the protocols of conscious patients to unconscious ones.

Inadequate resources

All higher levels of care (OT, HDU, ICU) were significantly associated with the *OFI inadequate resources* in both the adjusted and unadjusted analysis. The patients with the higher levels of care are most likely patients that have required more resources compared to the patients in the general ward. With more resources needed, the risk of a patient experiencing inadequate resources increases. The HDU had the largest odds for experiencing the OFI inadequate resources, both in the adjusted and the unadjusted analysis. It is possible that resources allocated to the HDU may be smaller compared to those allocated to the ICU, when considering the different types of patients at both levels of care. How to mitigate this problem is not easy, however. One study where nursing resources increased in the ICU showed no effect on patient mortality (28).

Missed diagnosis

No significance was found when comparing the general ward to the other levels of care when it comes to *missed diagnosis*. A theory from this author is that more diagnoses should be missed in the lower levels of care and then found in the later levels, since those patients could be assumed to stay longer at the hospital thus enabling for more time to find all diagnoses. However, this study shows no such association. Having a higher GCS at arrival to the hospital had an association with missed diagnosis. It is possible that medical personnel more thoroughly examine unconscious trauma patients compared to conscious trauma patients. *Missed diagnosis* also had a clear correlation with motorcycle and bicycle accidents. It is common for patients injured in motorcycle accidents to have several injuries (29). If some of these injuries remain undetected for some time it may explain some of the missed diagnoses. One study tentatively suggested that making sure to do a tertiary survey, meaning a survey of the entire patient after the patient is stabilised, might decrease missed injuries (30).

Discussion, continued

ISS was significantly associated with both OFI and with several categories of OFI. In all cases with a small odds ratio (1.05-1.08). This points towards there being an association with a higher

ISS and risk of OFI, however not by much. One previous study (18) correlating OFI with ISS showed a stronger association with a higher ISS and risk of OFI.

Being alive 30 days after trauma had a strong correlation with OFI in the adjusted analysis. One theory of why this could be the case is the inverted U shape of trauma. It is a theory discussed by the study group behind this paper, but it has not been specifically studied. The theory is that patients with both less severe injuries and very severe injuries do not experience OFI often. The patients with less severe injuries are not injured enough that their mortality or morbidity is affected when mistakes are made during their care. When mistakes are made caring for severely injured patients these mistakes do not affect the patient's outcome either since the patient is already too affected from the injury itself. These mistakes are therefore not considered OFI. Being alive 30-days after a traumatic injury would therefore have a correlation with OFI, since many patients dying within 30-days would have died regardless of the quality of care or mistakes made.

Factors affecting result

Many factors may have affected this study's result. In general, the way OFI is decided has some limitations. The system is based on the information contained in the patient's medical records, and it is possible that in a trauma situation there may be a lack of time which in turn may lead to incomplete note taking. It is possible that patients that have experienced OFI have not had them recorded.

In the case where the ED is the highest level of care a trauma patient receives, the injuries affecting the patient may be small enough to allow the patient to go home but may still long term affect the patient's morbidity. If the patient seeks medical treatment for their issues after some time has passed, it is possible that these problems, though based in trauma, may not be accurately classified as OFI. Out of the five categories in "Highest level of care", the ED has the fewest amount of category of OFI logged (21 patients), which make analysing the ED less reliable and harder to generalize.

One important variable which this study did not account for was how long the patient stayed at the hospital. It is reasonable to assume that a patient with a longer hospital stay may experience more OFI. This is supported by studies that show that an increased hospital stay leads to adverse events (31, 32).

All patient factors in this study were only analysed in an adjusted analysis and not in separate unadjusted analysis. It is possible that the association between OFI and patient factors would be different in an unadjusted analysis. In a previous study (18) on similar data, dying within 30 days of trauma correlated with OFI in an unadjusted analysis. In the adjusted analysis, the reverse was true – being alive within 30 days correlated with OFI. None of these analyses achieved statistical significance, however. Ideally, all patient factors should have been analysed separately to understand how they confound and correlate with OFI.

16 incidences of OFI were not logged in category of OFI but were still included in this study. Category of OFI includes *other errors*, which means it covers all possible OFI. This means that at least one category of OFI contained less patients than it should, making the analysis of highest level of care and category of OFI less accurate.

Strengths and weaknesses

The biggest strengths of this study are the large amount of patient data and the large sample size. There are many patients, especially in the group relating OFI with level of care. This makes the results from this study more generalisable. There are also many patients in the group where different levels of care are related to different categories of OFI. However, some of the categories of OFI contained few patients, thus making that statistical analysis less robust and lacking some precision. This study used data gathered over a long period of time which strengthens the external validity of its results.

Several similar studies have been conducted using the same trauma registry, though using different approaches to excluding factors, and using different timespans. This makes it possible to compare this study to these other studies and compare their validity. This is a strengthening factor for this study.

All data analysed in this study comes from one trauma centre in Stockholm, the capital of Sweden. This includes a patient group that may differ from other patient groups worldwide, and a trauma centre that may differ from other centres. This weakens the external validity of this study and makes implementing changes in other centres based on results from this study prone to error.

This study did not account for how long a patient stays at the hospital. The result from the analyses done in this study may have changed had this been controlled for. The result in this study shows that all higher levels of care have a correlation with OFI, but it is possible that this

correlation is due to patients in higher levels of care generally having a longer hospital stay, and thus a larger amount of time to experience an OFI. There is neither any information on in what care level a patient experienced OFI, only what the highest level of care a patient reached. The analysis done in this study only examine the correlation between a patient's highest level of care and OFI during an undetermined hospital stay, but there is no direct information about how many OFI happened in a specific level of care. This makes drawing large conclusions on what actions to take on specific levels of care to reduce OFI may be misguided.

The trauma registry used for this study contained no information on what reasoning there was for placing an OFI in a specific category. For example, there was no information on what type of resources were missing to deem an OFI as "inadequate resources". This makes choosing what changes to implement based on this study less precise.

This study is a retrospective cohort study, which means that it is possible that some data important to accurately correlate outcome in mortality and morbidity may not have been gathered. Data gathered may also have been incomplete or faulty, thus making any analysis prone to error. In a worst-case scenario, it is possible that the actual patient factors correlated with OFI may be wrongly registered or not registered at all, making analysing OFI meaningless. The risk of this is low, since the SweTrau registry has been validated and shown to have a large degree of accuracy (33), thus decreasing the risk of data gathering error having a large effect on this study's outcome.

Equity

This study is based on data from a type one trauma centre. This is a centre with very modern equipment and with well-trained personnel located in Stockholm, Sweden. The hospital uses routines and protocols that are well studied. It is possible that trauma patients in Sweden experience different types of traumas compared to patients worldwide. This means that there are some problems when trying to implement changes from this study on hospitals around the world. Even different hospital in Sweden which do not have type one trauma centres may have trouble interpreting the result from this study and implementing them in a way that is positive for their patients. There are even more possible problems when implementing the results from this study in a country far away from Sweden where there are different types of injuries, different training and different resources available.

In this study both men and women were included, as well as people of all ages except for children. There were more men included in the study, but women and men experienced OFI at

a similar rate comparatively (men were 69% of the patients and 72% of OFI, women were 31% of patients and had 28% of OFI).

Clinical implications

What can be taken from this study is the following – all higher levels of care compared to the general ward correlate with an increased risk of OFI. All higher levels of care correlate with inadequate resources when handling trauma patients compared to the general ward. This correlation points to the fact that there might be possible to reduce OFI by allocating more resources to these care levels. How this should be implemented is not easy to answer. In one systematic review (28) discussing nursing staff in the ICU, there was no clear change in patient morality based on how much staff a ward had. More resources will cost money, but if this leads to better patient mortality and morbidity it might be considered cost effective. Trauma patients, many who are younger than the typical patient, may have more working years left and thus this could be seen as cost effective in the long term for a society. A clear cost – benefit analysis would have to be made to see if it's worth it for higher resources to be allocated to the higher levels of care. A decrease in resources could be a potential predictor for an increase in OFI, which can be used as an argument against a decrease.

OT and HDU correlate with inadequate protocols, and OT and ICU correlate with a delay to treatment. This points to the fact that an overhaul of routines may be reasonable at these care levels, with one of the main goals being shortening the time to treatment.

There exists a correlation between HDU and clinical judgement error. This combined with the previous categories of OFI associated with the HDU may point to the fact that more experienced personnel as well as more personnel might offset some of the OFIs.

Physicians should be aware that trauma patients with a higher ISS have a slightly increased risk of OFI, and that patients with a higher GCS have an increased risk of experiencing missed diagnosis and inadequate protocols. Physicians should also be aware that patients who get injured in a motorcycle or bicycle accident have a higher risk of experiencing missed diagnoses.

Implementing changes based on this study is more likely to be successful the more similar the hospital is to the Karolinska hospital. The problem is especially high risk when it comes to low-income countries, where difference in routines and economy may result in unwanted factors emerging. Having clear routines for all care levels seems like something that is possible to

implement without too large of a cost, and something that may have good results even in lower-income areas.

Further studies

To gain the full benefit of this study, further analysing the current protocols of the OT, HDU and ICU at the Karolinska University hospital should be done, and analysing the resource allotment to the OT, HDU and ICU. After that, testing new implementation of protocols and allotment of resources should be done with the goal of seeing a decrease in OFI.

To further the understanding of how care level is associated with trauma, studying how OFI, level of hospital care and time of hospital stay correlates is a reasonable step.

Similar studies such as this one should be made using different patient data and different populations worldwide. These studies should preferably use the OFI variable, but they should at least use OFI-like variables. This would make it easier to compare this study and possible implementations from this study with other hospitals worldwide.

Conclusion

Higher levels of care correlated with a higher risk of OFI. The categories of OFI with strong association to level of care were in the OT, HDU and ICU inadequate resources, in the OT and HDU inadequate protocols, and in the OT and ICU delay to treatment. The HDU also had a strong association to clinical judgement error. The ED was associated with a lower risk of OFI. Few patient factors were clearly linked with OFI. To reduce the number of OFI, studying implementation of new routines and resource allocation in the OT, HDU and ICU should be the next step

Contributions

The study design was done by Martin Gerdin Wörnberg. Martin also did the ethics application and gathered the data from the trauma registry, as well as program a package in R containing the OFI variable. Martin also helped with proofreading. Anton Dalman made the programming code in R, analysed the data and wrote this paper. Continuously helping with the code and analysing results were Jonatan Attergrim, Johanna Berg, Kelvin Szolnoky and Martin Gerdin Wörnberg. Rstudio was used for programming.

Acknowledgements

I want to extend my gratitude to my supervisor Martin Gerdin Wärnberg for his continuous work in making this paper a reality. I would also like to thank my co-supervisors Jonatan Attergrim, Johanna Berg and Kelvin Szolnoky for their technical expertise both in analysing and creating the data. I want to thank Carl Skog, fellow student who worked with the same supervisor for having someone to bounce ideas off. I also want to thank Rebecka Wellén for proofreading my paper. Lastly, I would like to thank my coordinator Jan Jakobsson for his feedback when making this paper.

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Appendix

Appendix 1.

Multinomial Logistic Regression Results – Adjusted analysis complete

Outcome is category of opportunity for improvement, predictor is highest level of hospital care, age in years, patient sex, ASA-score preinjury, GCS at arrival, blood pressure at arrival, respiratory rate at arrival, injury mechanism and injury severity score. **Bold** p-value means the association is statistically significant. Injury mechanism is simplified. Most variables can be found in the SweTrau database (19). Category of OFI: clinical judgement error, delay in treatment, documentation issues, inadequate protocols, inadequate resources, missed diagnosis and other errors are subheadings.

Opportunity for improvement	Event Rate	OR ¹	95% CI ²	p-value
Clinical judgement error				
General Ward	52 / 2,804 (1.9%)	—	—	
Emergency Care	1 / 1,269 (0.08%)	0.06	0.01, 0.44	0.006
Operation Theater	45 / 1,356 (3.3%)	1.34	0.87, 2.06	0.2
Intermediate Care	20 / 332 (6.0%)	2.04	1.17, 3.58	0.012
ICU ³	32 / 823 (3.9%)	0.81	0.46, 1.45	0.5
Age in years	379 / 6,584 (5.8%)	1.01	1.00, 1.02	0.3
Patient sex				
Male	103 / 4,488 (2.3%)	—	—	
Female	47 / 2,096 (2.2%)	0.94	0.65, 1.36	0.7
ASA-score preinjury				
1	71 / 3,805 (1.9%)	—	—	
2	39 / 1,633 (2.4%)	0.94	0.61, 1.44	0.8
3	40 / 1,083 (3.7%)	1.12	0.67, 1.87	0.7
4	0 / 63 (0.00%)	0.00	0.00, 0.00	<0.001
GCS⁴ at arrival	379 / 6,584 (5.8%)	1.06	0.97, 1.15	0.2
Blood pressure at arrival	379 / 6,584 (5.8%)	1.00	1.0, 1.01	0.7
Respiratory rate at arrival	379 / 6,584 (5.8%)	1.00	0.97, 1.04	0.8
Injury mechanism				
1. Vehicle accident	18 / 973 (1.8%)	—	—	
2. Motorcycle accident	9 / 535 (1.7%)	0.61	0.27, 1.40	0.2
3. Bicycle accident	13 / 566 (2.3%)	0.92	0.44, 1.92	0.8
4. Pedestrian accident	7 / 231 (3.0%)	1.08	0.43, 2.68	0.9
5. Accident other vehicle	0 / 69 (0.00%)	0.00	0.00, 0.00	<0.001
6. Gunshot	2 / 218 (0.92%)	0.32	0.07, 1.45	0.14
7. Knife	9 / 783 (1.1%)	0.58	0.25, 1.33	0.2
8. Blunt object	9 / 672 (1.3%)	0.62	0.28, 1.41	0.3
9. Fall in the same elevation	24 / 965 (2.5%)	0.87	0.44, 1.71	0.7
10. Fall from other elevation	56 / 1,490 (3.8%)	1.25	0.72, 2.18	0.4
11. Explosion injury	0 / 24 (0.00%)	0.01	0.01, 0.01	<0.001
12. Other injury	3 / 58 (5.2%)	2.25	0.62, 8.22	0.2
ISS⁵	379 / 6,584 (5.8%)	1.07	1.05, 1.09	<0.001
Delay in treatment				
General Ward	10 / 2,804 (0.36%)	—	—	
Emergency Care	2 / 1,269 (0.16%)	0.52	0.11, 2.37	0.4
Operation Theater	23 / 1,356 (1.7%)	4.12	1.89, 9.01	<0.001
Intermediate Care	3 / 332 (0.90%)	2.44	0.65, 9.14	0.2
ICU ³	15 / 823 (1.8%)	3.15	1.17, 8.45	0.023
Age in years	379 / 6,584 (5.8%)	1.00	0.98, 1.02	0.8
Patient sex				

Male	38 / 4,488 (0.85%)	—	—	
Female	15 / 2,096 (0.72%)	1.11	0.58, 2.14	0.8
ASA-score preinjury				
1	26 / 3,805 (0.68%)	—	—	
2	21 / 1,633 (1.3%)	1.69	0.90, 3.21	0.11
3	6 / 1,083 (0.55%)	0.65	0.23, 1.89	0.4
4	0 / 63 (0.00%)	0.01	0.01, 0.01	<0.001
GCS⁴ at arrival	379 / 6,584 (5.8%)	0.93	0.83, 1.03	0.15
Blood pressure at arrival	379 / 6,584 (5.8%)	1.00	0.99, 1.01	>0.9
Respiratory rate at arrival	379 / 6,584 (5.8%)	1.01	0.97, 1.07	0.5
Injury mechanism				
1. Vehicle accident	5 / 973 (0.51%)	—	—	
2. Motorcycle accident	4 / 535 (0.75%)	1.10	0.29, 4.15	0.9
3. Bicycle accident	1 / 566 (0.18%)	0.31	0.04, 2.63	0.3
4. Pedestrian accident	3 / 231 (1.3%)	1.79	0.41, 7.79	0.4
5. Accident other vehicle	3 / 69 (4.3%)	5.69	1.25, 25.9	0.025
6. Gunshot	6 / 218 (2.8%)	3.26	0.94, 11.4	0.064
7. Knife	6 / 783 (0.77%)	1.12	0.33, 3.82	0.9
8. Blunt object	7 / 672 (1.0%)	1.68	0.52, 5.43	0.4
9. Fall in the same elevation	8 / 965 (0.83%)	1.32	0.39, 4.44	0.7
10. Fall from other elevation	10 / 1,490 (0.67%)	0.89	0.30, 2.67	0.8
11. Explosion injury	0 / 24 (0.00%)	0.03	0.03, 0.04	<0.001
12. Other injury	0 / 58 (0.00%)	0.01	0.01, 0.01	<0.001
ISS⁵	379 / 6,584 (5.8%)	1.02	0.99, 1.05	0.2
Documentation Issues				
General Ward	6 / 2,804 (0.21%)	—	—	
Emergency Care	0 / 1,269 (0.00%)	0.00	0.00, 0.00	<0.001
Operation Theater	3 / 1,356 (0.22%)	0.85	0.19, 3.92	0.8
Intermediate Care	0 / 332 (0.00%)	0.01	0.01, 0.01	<0.001
ICU ³	1 / 823 (0.12%)	0.30	0.02, 4.50	0.4
Age in years	379 / 6,584 (5.8%)	1.02	0.98, 1.06	0.5
Patient sex				
Male	7 / 4,488 (0.16%)	—	—	
Female	3 / 2,096 (0.14%)	0.88	0.20, 3.91	0.9
ASA-score preinjury				
1	7 / 3,805 (0.18%)	—	—	
2	1 / 1,633 (0.06%)	0.27	0.03, 2.35	0.2
3	2 / 1,083 (0.18%)	0.86	0.12, 6.11	0.9
4	0 / 63 (0.00%)	0.08	0.08, 0.08	<0.001
GCS⁴ at arrival	379 / 6,584 (5.8%)	0.91	0.67, 1.25	0.6
Blood pressure at arrival	379 / 6,584 (5.8%)	1.00	0.97, 1.03	>0.9
Respiratory rate at arrival	379 / 6,584 (5.8%)	1.00	0.88, 1.13	>0.9
Injury mechanism				
1. Vehicle accident	3 / 973 (0.31%)	—	—	
2. Motorcycle accident	1 / 535 (0.19%)	0.46	0.05, 4.59	0.5
3. Bicycle accident	0 / 566 (0.00%)	0.00	0.00, 0.00	<0.001
4. Pedestrian accident	2 / 231 (0.87%)	1.99	0.31, 12.9	0.5
5. Accident other vehicle	0 / 69 (0.00%)	0.01	0.01, 0.02	<0.001
6. Gunshot	1 / 218 (0.46%)	1.22	0.11, 13.5	0.9
7. Knife	1 / 783 (0.13%)	0.33	0.03, 3.36	0.3
8. Blunt object	0 / 672 (0.00%)	0.00	0.00, 0.00	<0.001
9. Fall in the same elevation	0 / 965 (0.00%)	0.00	0.00, 0.00	<0.001
10. Fall from other elevation	2 / 1,490 (0.13%)	0.30	0.05, 1.81	0.2

11. Explosion injury	0 / 24 (0.00%)	0.08	0.07, 0.08	<0.001
12. Other injury	0 / 58 (0.00%)	0.03	0.03, 0.03	<0.001
ISS⁵	379 / 6,584 (5.8%)	1.02	0.94, 1.10	0.7
Inadequate protocols				
General Ward	2 / 2,804 (0.07%)	—	—	
Emergency Care	0 / 1,269 (0.00%)	0.01	0.01, 0.01	<0.001
Operation Theater	9 / 1,356 (0.66%)	6.76	1.48, 30.8	0.014
Intermediate Care	3 / 332 (0.90%)	7.20	1.16, 44.5	0.034
ICU ³	4 / 823 (0.49%)	4.50	0.71, 28.4	0.11
Age in years	379 / 6,584 (5.8%)	1.04	1.01, 1.08	0.009
Patient sex				
Male	12 / 4,488 (0.27%)	—	—	
Female	6 / 2,096 (0.29%)	1.02	0.34, 3.01	>0.9
ASA-score preinjury				
1	10 / 3,805 (0.26%)	—	—	
2	3 / 1,633 (0.18%)	0.40	0.10, 1.56	0.2
3	5 / 1,083 (0.46%)	0.50	0.12, 2.08	0.3
4	0 / 63 (0.00%)	0.03	0.03, 0.03	<0.001
GCS⁴ at arrival	379 / 6,584 (5.8%)	1.76	1.37, 2.27	<0.001
Blood pressure at arrival	379 / 6,584 (5.8%)	0.99	0.98, 1.01	0.5
Respiratory rate at arrival	379 / 6,584 (5.8%)	0.95	0.87, 1.05	0.3
Injury mechanism				
1. Vehicle accident	2 / 973 (0.21%)	—	—	
2. Motorcycle accident	3 / 535 (0.56%)	2.06	0.32, 13.1	0.4
3. Bicycle accident	1 / 566 (0.18%)	0.80	0.07, 8.90	0.9
4. Pedestrian accident	1 / 231 (0.43%)	0.99	0.08, 11.6	>0.9
5. Accident other vehicle	0 / 69 (0.00%)	0.03	0.03, 0.03	<0.001
6. Gunshot	1 / 218 (0.46%)	2.21	0.18, 27.5	0.5
7. Knife	0 / 783 (0.00%)	0.00	0.00, 0.00	<0.001
8. Blunt object	3 / 672 (0.45%)	1.87	0.30, 11.6	0.5
9. Fall in the same elevation	4 / 965 (0.41%)	1.19	0.19, 7.32	0.8
10. Fall from other elevation	3 / 1,490 (0.20%)	0.57	0.09, 3.45	0.5
11. Explosion injury	0 / 24 (0.00%)	0.14	0.14, 0.15	<0.001
12. Other injury	0 / 58 (0.00%)	0.04	0.04, 0.04	<0.001
ISS⁵	379 / 6,584 (5.8%)	1.07	1.02, 1.12	0.006
Inadequate resources				
General Ward	19 / 2,804 (0.68%)	—	—	
Emergency Care	4 / 1,269 (0.32%)	0.51	0.17, 1.51	0.2
Operation Theater	26 / 1,356 (1.9%)	2.20	1.19, 4.07	0.012
Intermediate Care	14 / 332 (4.2%)	5.28	2.53, 11.0	<0.001
ICU ³	25 / 823 (3.0%)	3.05	1.46, 6.35	0.003
Age in years	379 / 6,584 (5.8%)	0.99	0.98, 1.01	0.2
Patient sex				
Male	66 / 4,488 (1.5%)	—	—	
Female	22 / 2,096 (1.0%)	0.98	0.58, 1.63	>0.9
ASA-score preinjury				
1	53 / 3,805 (1.4%)	—	—	
2	20 / 1,633 (1.2%)	0.81	0.46, 1.40	0.4
3	14 / 1,083 (1.3%)	0.91	0.43, 1.90	0.8
4	1 / 63 (1.6%)	1.59	0.19, 13.2	0.7
GCS⁴ at arrival	379 / 6,584 (5.8%)	1.08	0.96, 1.20	0.2
Blood pressure at arrival	379 / 6,584 (5.8%)	1.01	1.00, 1.01	0.2
Respiratory rate at arrival	379 / 6,584 (5.8%)	0.99	0.95, 1.03	0.7

Injury mechanism				
1. Vehicle accident	11 / 973 (1.1%)	—	—	
2. Motorcycle accident	13 / 535 (2.4%)	1.45	0.63, 3.34	0.4
3. Bicycle accident	6 / 566 (1.1%)	0.81	0.29, 2.24	0.7
4. Pedestrian accident	2 / 231 (0.87%)	0.58	0.13, 2.72	0.5
5. Accident other vehicle	0 / 69 (0.00%)	0.00	0.00, 0.00	<0.001
6. Gunshot	4 / 218 (1.8%)	0.86	0.26, 2.83	0.8
7. Knife	12 / 783 (1.5%)	1.06	0.45, 2.48	0.9
8. Blunt object	7 / 672 (1.0%)	0.80	0.31, 2.09	0.7
9. Fall in the same elevation	11 / 965 (1.1%)	0.92	0.36, 2.31	0.9
10. Fall from other elevation	20 / 1,490 (1.3%)	0.86	0.41, 1.83	0.7
11. Explosion injury	1 / 24 (4.2%)	2.35	0.27, 20.3	0.4
12. Other injury	1 / 58 (1.7%)	0.94	0.12, 7.64	>0.9
ISS⁵	379 / 6,584 (5.8%)	1.05	1.02, 1.07	<0.001
Missed diagnosis				
General Ward	23 / 2,804 (0.82%)	—	—	
Emergency Care	10 / 1,269 (0.79%)	1.00	0.45, 2.24	>0.9
Operation Theater	15 / 1,356 (1.1%)	1.15	0.57, 2.31	0.7
Intermediate Care	3 / 332 (0.90%)	1.22	0.35, 4.28	0.8
ICU ³	6 / 823 (0.73%)	1.17	0.39, 3.51	0.8
Age in years	379 / 6,584 (5.8%)	1.00	0.98, 1.02	>0.9
Patient sex				
Male	36 / 4,488 (0.80%)	—	—	
Female	21 / 2,096 (1.0%)	1.53	0.85, 2.75	0.2
ASA-score_preinjury				
1	33 / 3,805 (0.87%)	—	—	
2	17 / 1,633 (1.0%)	1.37	0.73, 2.57	0.3
3	7 / 1,083 (0.65%)	1.16	0.44, 3.05	0.8
4	0 / 63 (0.00%)	0.02	0.02, 0.02	<0.001
GCS⁴ at arrival	379 / 6,584 (5.8%)	1.79	1.05, 3.05	0.033
Blood pressure at arrival	379 / 6,584 (5.8%)	1.00	0.99, 1.01	>0.9
Respiratory rate at arrival	379 / 6,584 (5.8%)	0.98	0.92, 1.04	0.5
Injury mechanism				
1. Vehicle accident	7 / 973 (0.72%)	—	—	
2. Motorcycle accident	14 / 535 (2.6%)	3.61	1.40, 9.31	0.008
3. Bicycle accident	12 / 566 (2.1%)	3.10	1.19, 8.09	0.021
4. Pedestrian accident	1 / 231 (0.43%)	0.51	0.06, 4.20	0.5
5. Accident other vehicle	1 / 69 (1.4%)	1.95	0.23, 16.2	0.5
6. Gunshot	0 / 218 (0.00%)	0.00	0.00, 0.00	<0.001
7. Knife	2 / 783 (0.26%)	0.39	0.08, 1.93	0.3
8. Blunt object	5 / 672 (0.74%)	1.13	0.35, 3.65	0.8
9. Fall in the same elevation	3 / 965 (0.31%)	0.47	0.11, 1.94	0.3
10. Fall from other elevation	12 / 1,490 (0.81%)	1.00	0.38, 2.60	>0.9
11. Explosion injury	0 / 24 (0.00%)	0.03	0.03, 0.03	<0.001
12. Other injury	0 / 58 (0.00%)	0.01	0.01, 0.01	<0.001
ISS⁵	379 / 6,584 (5.8%)	1.04	1.00, 1.08	0.036
Other errors				
General Ward	1 / 2,804 (0.04%)	—	—	
Emergency Care	0 / 1,269 (0.00%)	0.00	0.00, 0.00	<0.001
Operation Theater	0 / 1,356 (0.00%)	0.00	0.00, 0.00	<0.001
Intermediate Care	0 / 332 (0.00%)	0.02	0.02, 0.02	<0.001
ICU ³	2 / 823 (0.24%)	1.74	0.08, 37.6	0.7
Age in years	379 / 6,584 (5.8%)	1.00	0.92, 1.09	>0.9

Patient sex				
Male	3 / 4,488 (0.07%)	—	—	
Female	0 / 2,096 (0.00%)	0.00	0.00, 0.00	<0.001
ASA-score_preinjury				
1	2 / 3,805 (0.05%)	—	—	
2	0 / 1,633 (0.00%)	0.00	0.00, 0.00	<0.001
3	1 / 1,083 (0.09%)	0.94	0.01, 64.2	>0.9
4	0 / 63 (0.00%)	0.06	0.05, 0.06	<0.001
GCS⁴ at arrival	379 / 6,584 (5.8%)	0.81	0.58, 1.12	0.2
Blood pressure at arrival	379 / 6,584 (5.8%)	1.00	0.97, 1.04	0.8
Respiratory rate at arrival	379 / 6,584 (5.8%)	1.02	0.87, 1.19	0.8
Injury mechanism				
1. Vehicle accident	0 / 973 (0.00%)	—	—	
2. Motorcycle accident	0 / 535 (0.00%)	0.03	0.03, 0.03	<0.001
3. Bicycle accident	0 / 566 (0.00%)	0.05	0.05, 0.05	<0.001
4. Pedestrian accident	0 / 231 (0.00%)	0.25	0.25, 0.25	<0.001
5. Accident other vehicle	1 / 69 (1.4%)	707	69.8, 7,160	<0.001
6. Gunshot	0 / 218 (0.00%)	0.23	0.23, 0.23	<0.001
7. Knife	1 / 783 (0.13%)	204	19.3, 2,161	<0.001
8. Blunt object	0 / 672 (0.00%)	0.09	0.09, 0.09	<0.001
9. Fall in the same elevation	1 / 965 (0.10%)	46.3	2.30, 934	0.012
10. Fall from other elevation	0 / 1,490 (0.00%)	0.01	0.01, 0.01	<0.001
11. Explosion injury	0 / 24 (0.00%)	0.88	0.88, 0.88	<0.001
12. Other injury	0 / 58 (0.00%)	0.73	0.73, 0.73	<0.001
ISS⁵	379 / 6,584 (5.8%)	1.05	0.96, 1.15	0.3

¹OR = Odds Ratio, ²CI = Confidence Interval, ³ICU = Intensive care unit, ⁴GCS = Glasgow coma scale,

⁵ISS = Injury severity score.