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

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**Original article**

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**Sources of funding:**

The Swedish Society of Medicine, grant number SLS-973387 &

The Swedish Carnegie Hero Fund

**Data availability**

The data that support the findings of this study are available following the approval of a project suggesting to use 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.

# Abstract

*Background*: Trauma is one of the leading causes of morbidity and mortality worldwide. Morbidity and mortality review of specific 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 used data from the Karolinska University Hospital trauma registry and the trauma care quality database between 2017 and 2021. Our outcome was OFI as defined by the morbidity and mortality review at Karolinska University Hospital. 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, intubation status and time to CT and intervention.

*Results*: OFI was identified in 276 (5.94%) out of 4643 patients. The median age for patients with OFI was 49 compared to 42 in patients without OFI. Age, highest hospital care level, ISS, respiratory rate, systolic blood pressure, GCS, survival after 30 days and intubation 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 are at the highest odds of OFI. Future research should focus on identifying reasons why these factors are associated with higher odds of OFI.

# Introduction

Trauma is one of the leading causes of mortality and morbidity in all age groups globally [[1](#ref-David2021),[2](#ref-Ono2021)]. There are approximately 4.5 million global deaths each year due to trauma [[3](#ref-James2020)], and it is one of the top contributors to disease burden worldwide, measured by disability-adjusted life years [[4](#ref-Murray1996),[5](#ref-Haagsma2015)]. Trauma care is resource-intensive and is one of the most common reasons for critical care unit admission [[6](#ref-Prin2016)].

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](#ref-Donabedian1988)]. There are several methods to improve the quality of trauma care, with multidisciplinary morbidity and mortality review being a key method to address all three components of this framework [[8](#ref-WHO2009)].

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 range between 20 and 76% [[11](#ref-Ghorbani2018),[14](#ref-Esposito_2003),[15](#ref-Sanddal_2011)], and common OFI relate to airway management, management of traumatic brain injury, fluid replacement, delays in prehospital transport and delays to surgery [[9](#ref-Zafarghandi2003),[13](#ref-Roy_2017),[16](#ref-Teixeira2007),[17](#ref-OReilly2013)].

Whereas countless 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. Such research could help identify patients and processes likely to benefit from quality improvement. The aim of this study was to assess how patient and process factors are associated with OFI in trauma care.

# Methods

### Study design

We used data from the Karolinska University Hospital trauma registry, part of the Swedish National Trauma Registry (SweTrau) [[18](#ref-Swetrau2020)], as well as the hospital’s local trauma care quality database. The content of the trauma registry has been previously described [REF]. 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 OFI. We linked the trauma registry and trauma care quality database using personal identification numbers and extracted factors potentially associated with OFI. We used bi- and multivariable logistic regression to determine associations between these factors and OFI.

### Setting

The Karolinska University Hospital in Solna receives all patients with major trauma in Stockholm [[21](#ref-traumalarmskriterier2017)] and is equivalent to a level one trauma center, with direct access to radiology, intervention, surgery, intensive care and consultants in all associated specialities [[22](#ref-Social2015),[23](#ref-NKS2020)]. All trauma patients presenting to Karolinska University Hospital are included in a morbidity and mortality screening process using a combination of manual review by specialised nurses and audit filters. The audit filters, shown in table X, are used to identify patients in which OFI are more likely. If the specialized nurses judge that there is a potential OFI, the patient is discussed at a morbidity and mortality conference. During these multidisciplinary conferences the patient cases are reviewed by experienced specialists from all the disciplines and professions involved in the 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 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 morbidity and mortality screening process between 2017 and 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, and defined as a binary variable with the levels “Yes - At least one OFI identified” and “No - No OFI identified”. Data on this outcome was extracted from the trauma care quality database.

**Patient and process factors** We selected factors from the trauma registry, based on the locally used audit filters shown in table X, standard epidemiological factors and factors frequently registered in Swetrau. The categorical variables were sex, survival after 30 days, highest hospital care level, GCS, respiratory rate, systolic blood pressure, working hours, weekend, time from arrival at the hospital until first CT and if the patient was intubated. We also included the continuous variables age and ISS.

In the trauma registry, both systolic blood pressure and respiratory rate are registered as either a continuous value or a Revised Trauma Score category [REF]. We converted the continuous values of systolic blood pressure and respiratory rate, if registered, and GCS into the corresponding Revised Trauma Score category and included a missing category. We used pre-hospital, pre-intubation, values for respiratory rate and GCS for patients who were intubated before arrival at the emergency department.

The variable highest hospital care level is divided into five categories: Emergency Department, General Ward, Surgical Ward, High Dependency Unit and Critical Care Unit. Patients who need a higher level of care than that provided in a General Ward but who do not require intensive care are admitted to High Dependency Units such as dedicated trauma wards with more extensive monitoring. Patients with multi-organ failure or who require mechanical ventilation are admitted to Critical Care Units [[19](#ref-Utstein2009)].

We also included variables denoting if the patient arrived to hospital during working hours, defined as between 8.00 a.m. and 5 p.m, or during a weekend, defined as Saturday or Sunday.

### Statistical analysis

We performed a complete case analysis after handling missing values in systolic blood pressure, respiratory rate, and GCS as described above. We present baseline characteristics using descriptive statistics. We used bivariable logistic regression to determine unadjusted associations and multivariable logistic regression to determine adjusted associations between patient and process factors and OFI. We present results as odds ratios (OR) with associated 95% confidence interval. We used a significance level of 5%. The programming language R was used for all analyses [[24](#ref-Rstudio2022)]. All statistical analysis were 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 5216 patients included in both the trauma registry and trauma care quality database between 2017 and 2021, 34 patients were excluded due to missing data or age under 15, leaving a total of 5182 patients eligible for the study. The variable with the most missing data was GCS, for which values was missing in169 (3.2%) patients. The number of patients with missing data in each variable is shown in Table 4.2.

The baseline characteristics are presented in Table 4.1. Among the 5182 included patients, 300 (5.8%) patients had OFI. 3520 (67.9%) were male and the median age was 43 [15, 100] years. The median ISS was 6 [0, 75]. The number of patients who arrived outside of working hours was 3060 (59%), and 3511 (67%) patients arrived during weekdays. A total of 203 (3.9%) patients died within 30 days. Figures 2A-D and 3A-F show the distributions of OFI across categorical variables. OFI were most common in

The unadjusted and adjusted associations of selected factors with OFI are shown in Table 4.3.

The following factors were significantly associated with OFI only in the unadjusted analysis: A respiratory rate higher than 29 compared to a respiratory rate between 10 and 29 (OR 2.11, 95% CI 1.25, 3.37, p-value 0.003), a systolic blood pressure between 50 and 75 (OR 4.05, 95% CI 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 to a systolic blood pressure of more than 89, and intubation in the emergency department compared to no intubation (OR 2.72, 95% CI 1.89, 3.83, p-value <0.001).

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Age (aOR 1.01, 95% CI 1.00-1.01, p-value 0.008) and ISS (aOR 1.05, 95% CI 1.04, 1.07, p-value < 0.001) were significantly associated with higher odds of OFI in both the unadjusted and adjusted analysis. A GCS between 9 and 12 was in the unadjusted analysis significantly associated with higher odds of OFI compared to a GCS between 13 and 15 (OR 1.77, 95% CI 1.06, 2.78, p-value 0.020). In the adjusted analysis however, only missing GCS was significantly associated with lower odds of OFI (aOR 0.33, 95% CI 0.12, 0.94, p-value 0.038) whereas a GCS between 9 and 12 now was associated with lower odds of OFI (aOR 0.89, 95% CI 0.52, 1.52, p-value 0.67), but not significantly so.

A time to first CT between 31 and 60 minutes was in the unadjusted analysis significantly associated with higher odds of OFI compared to no CT (OR 1.66, 95% CI 1.06, 2.70, p-value 0.032). This association remained significant in the adjusted analysis (OR 1.75, 95% CI 1.08, 2.86, p-value 0.024), but in this analysis a time between 61 and 90 minutes (aOR 2.85, 95% CI 1.64, 4.96, p-value < 0.001) and a time over 90 minutes (aOR 1.97, 95% CI 1.18, 3.29, p-value 0.010) were also associated with significantly higher odds of OFI.

Compared to care in the emergency department, all higher levels of care were significantly associated with higher odds of OFI in both the unadjusted and adjusted analyses. The higher odds were most pronounced in patients treated in a High Dependency Unit (aOR 8.25, 95% CI 4.02, 16.9, p-value < 0.001).

# Sex, survival after 30 days, working hours, and weekend were not significantly associated with OFI in neither the unadjusted nor the adjusted analysis.Discussion

We found that age, highest hospital care level, ISS, GCS, respiratory rate, systolic blood pressure, time to first CT and intubation are significantly associated with OFI in adult trauma patients. In contrast to previous research on sex-based disparities in trauma patient outcome [[25](#ref-Marcolini2019),[26](#ref-Duong2020)],we did not find sex to be significantly associated with OFI. We did not find working hours nor weekend to be significantly associated with OFI.

The factor most strongly associated with OFI was being treated in high dependency units or critical care units, . This means that OFI are more common in the care of patients treated in these units compared to in the care of those treated in the emergency department. A previous study in the US has shown that more than half of the preventable and probably preventable deaths occur in critical care units [[16](#ref-Teixeira2007)]. This could be explained by the complexity, severeness and amount of intervention needed for the patients treated in these units.

According to the same study the most prevalent OFI were related to airway management and perioperative care and patients requiring these interventions are usually found in critical care units [[27](#ref-Teixeira2009)]. The patients in high dependency units are also complex, although these wards lack the access to the resources and personnel found in critical care units. This could explain why the odds ratio of OFI is higher in high dependency units compared to critical care units. The low frequency of OFI in patiens treated in the emergency department as the highest hospital care level can be explained by these patients having less severe trauma and therefore requiring less interventions.

Time to first CT was significantly associated with higher odds of OFI and has in previous studies been associated with poor outcomes [28, 29]. . This association is complex because CT is not a priority when acute intervention is needed, and event if the delay to CT could be the cause of OFI it could also be that patients with a longer time to CT have more interventions and are therefore more prone to OFI. Age was significantly associated with higher odds of OFI and the median age was eight years higher in patients with OFI. The comorbidity, frailty, and differences in clinical presentation of the elderly could be an explanation for higher odds of OFI in these patients. Previous studies have found higher mortality in elderly patients even though there were no major differences in injury severity compared to younger patients [[30](#ref-MacDonald_2020),[31](#ref-Earl_Royal_2016)].

We also found ISS to be significantly associated with OFI and the median ISS was 17 in the group with OFI compared to five in patients without OFI, meaning that OFI are more likely in patients with severe trauma. 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 variables indicate more severe trauma, which was more effectively captured by ISS in the adjusted analysis.

OFI was identified in 7.4% of those who died within 30 days. A study published in 2018 from the Karolinska University Hospital identified at least one preventable error in 21% of all trauma deaths, although only 4% of all trauma deaths were found to be preventable [[11](bookmark://ref-Ghorbani2018)]. An explanation for the comparably lower number of OFI in those who died in our study is the criteria used to determine the presence of OFI differed, although the adoption of new treatment strategies and the implementation of quality improvement programs can also have played a role.

Our study had several limitations. Although all trauma one 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 possibility some patients with OFI were not selected for review by the conference and therefore registered as a patient without OFI. Furthermore this study was a single centre study, and its results illustrates the situation in Stockholm.

In conclusion, the care of patients with more severe trauma leading and higher hospital care level was found to be significantly associated with OFI after adjusting for other factors. Future research should focus on identifying reasons why the care of patients with severe trauma is more susceptible for OFI and how this can be alleviated.

# Figure legends

Figure 1: *Flowchart describing the process of selection and results for morbidity and mortality conferences, with number of patients in each stage between 2014-2017. OFI = Opportunities for improvement.*

Figure 2: *Opportunities for improvement presented in highest hospital care level, respiratory rate, Glasgow coma scale and systolic blood pressure. ED: Emergency Department, GW: General Ward, SW: Surgical Ward, HDU: High Dependency Unit, CCU: Critical Care Unit.*

Figure 3: *Opportunities for improvement presented in the remaining factors. Pre = Intubated before arrival at the emergency department, ED = Intubated in the Emergency Department.*

*Figure 4: Box plot displaying the distribution of patients with OFI and those without in the continuous variables age and ISS. ISS = Injury Severity Score*

# References

1 David SD, Roy N, Solomon H, Lundborg CS, Wärnberg MG. Measuring post-discharge socioeconomic and quality of life outcomes in trauma patients: A scoping review. *Journal of Patient-Reported Outcomes* 2021;**5**. doi:[10.1186/s41687-021-00346-6](https://doi.org/10.1186/s41687-021-00346-6)

2 Ono Y, Iwasaki Y, Hirano T, Hashimoto K, Kakamu T, Inoue S, *et al.* Impact of emergency physician-staffed ambulances on preoperative time course and survival among injured patients requiring emergency surgery or transarterial embolization: A retrospective cohort study at a community emergency department in japan. *PLOS ONE* 2021;**16**:e0259733.

3 James SL, Castle CD, Dingels ZV, Fox JT, Hamilton EB, Liu Z, *et al.* Estimating global injuries morbidity and mortality: Methods and data used in the global burden of disease 2017 study. *Injury Prevention* 2020;**26**:i125–53.

4 Murray CJ, Lopez AD, Organization WH, others. *The global burden of disease: A comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020: summary*. World Health Organization 1996.

5 al. JAH et. The global burden of injury: Incidence, mortality, disability-adjusted life years and time trends from the global burden of disease study 2013. *Injury Prevention* 2015;**22**:3–18.

6 Prin M, Li G. Complications and in-hospital mortality in trauma patients treated in intensive care units in the united states, 2013. *Injury Epidemiology* 2016;**3**. doi:[10.1186/s40621-016-0084-5](https://doi.org/10.1186/s40621-016-0084-5)

7 Donabedian A. The quality of care. *JAMA* 1988;**260**:1743.

8 World health organization, guidelines for trauma quality improvement programmes [internet]. World health organization. [https://apps.who.int/iris/bitstream/handle/10665/44061/9789241597746%7B/\_%7Deng.pdf;jsessionid=E90A5736D4F3786CCBAA19E19E4EEF5F?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/44061/9789241597746%7b/_%7deng.pdf;jsessionid=E90A5736D4F3786CCBAA19E19E4EEF5F?sequence=1) (accessed 2022).

9 Zafarghandi M-R, Modaghegh M-HS, Roudsari BS. Preventable trauma death in tehran: An estimate of trauma care quality in teaching hospitals. *The Journal of Trauma: Injury, Infection, and Critical Care* 2003;**55**:459–65.

10 Konadu-Yeboah D, Kwasi K, Donkor P, Gudugbe S, Sampen O, Okleme A, *et al.* Preventable trauma deaths and corrective actions to prevent them: A 10-year comparative study at the komfo anokye teaching hospital, kumasi, ghana. *World Journal of Surgery* 2020;**44**:3643–50.

11 Ghorbani P, Strömmer L. Analysis of preventable deaths and errors in trauma care in a scandinavian trauma level-i centre. *Acta Anaesthesiologica Scandinavica* 2018;**62**:1146–53.

12 Ivatury RR, Guilford K, Malhotra AK, Duane T, Aboutanos M, Martin N. Patient safety in trauma: Maximal impact management errors at a level i trauma center. *Journal of Trauma: Injury, Infection and Critical Care* 2008;**64**:265–72.

13 Roy N, Veetil DK, Khajanchi MU, Kumar V, Solomon H, Kamble J, *et al.* Learning from 2523 trauma deaths in india- opportunities to prevent in-hospital deaths. *BMC Health Services Research* 2017;**17**. doi:[10.1186/s12913-017-2085-7](https://doi.org/10.1186/s12913-017-2085-7)

14 Esposito TJ, Sanddal TL, Reynolds SA, Sanddal ND. Effect of a voluntary trauma system on preventable death and inappropriate care in a rural state. *The Journal of Trauma: Injury, Infection, and Critical Care* 2003;**54**:663–70.

15 Sanddal TL, Esposito TJ, Whitney JR, Hartford D, Taillac PP, Mann NC, *et al.* Analysis of preventable trauma deaths and opportunities for trauma care improvement in utah. *Journal of Trauma: Injury, Infection and Critical Care* 2011;**70**:970–7.

16 Teixeira PGR, Inaba K, Hadjizacharia P, Brown C, Salim A, Rhee P, *et al.* Preventable or potentially preventable mortality at a mature trauma center. *Journal of Trauma: Injury, Infection, and Critical Care* 2007;**63**:1338–47.

17 O’Reilly D, Mahendran K, West A, Shirley P, Walsh M, Tai N. Opportunities for improvement in the management of patients who die from haemorrhage after trauma. *British Journal of Surgery* 2013;**100**:749–55.

18 Swetrau, årsrapport SweTrau 2019 [internet]. Annual report, stockholm: Svenska traumaregister. [https://rcsyd.se/swetrau/wp-content/uploads/sites/10/2020/09/A%CC%8Arsrapport-SweTrau-2019.pdf](https://rcsyd.se/swetrau/wp-content/uploads/sites/10/2020/09/Årsrapport-SweTrau-2019.pdf) (accessed 2022).

19 Ringdal KG et al Coats TJ. The utstein trauma template for uniform reporting of data following major trauma: Data dictionary. Version 1.1.1. European trauma registry network, 2008. [internet]. <https://rcsyd.se/swetrau/wp-content/uploads/sites/10/2015/10/Revised_Utstein_Template_-_Data_Dictionary_v1.1.1.pdf> (accessed 2022).

20 Dick WF, Baskett PJF. Recommendations for uniform reporting of data following major trauma the utstein style. *Resuscitation* 1999;**42**:81–100.

21 Föreningen Ledningsansvariga i Svensk Ambulanssjukvård et al. Nationella traumalarmskriterier 2017: Säker traumavård. Föreningen ledningsansvariga i svensk ambulanssjukvård, 2017. [internet]. <https://lof.se/filer/trauma-broschyr.pdf> (accessed 2022).

22 Socialstyrelsen, traumavård vid allvarlig händelse socialstyrelsen 2015 [internet]. <https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2015-11-5.pdf> (accessed 2022).

23 Karolinska universitetssjukhuset solna, traumamanual karolinska universitetssjukhuset solna 2020 [internet]. <https://traumarummet.files.wordpress.com/2020/09/traumamanualen-2020.pdf> (accessed 2022).

24 RStudio Team. *RStudio: Integrated development environment for r*. Boston, MA: RStudio, PBC. 2020. <http://www.rstudio.com/>

25 Marcolini EG, Albrecht JS, Sethuraman KN, Napolitano LM. Gender disparities in trauma care. *Anesthesiology Clinics* 2019;**37**:107–17.

26 Duong WQ, Grigorian A, Farzaneh C, Nahmias J, Chin T, Schubl S, *et al.* Racial and sex disparities in trauma outcomes based on geographical region. *The American Surgeon* 2020;**87**:988–93.

27 Teixeira PGR. Preventable morbidity at a mature trauma center. *Archives of Surgery* 2009;**144**:536.

28 Katayama Y, Kitamura T, Hirose T, Kiguchi T, Matsuyama T, Sado J, *et al.* Delay of computed tomography is associated with poor outcome in patients with blunt traumatic aortic injury. *Medicine* 2018;**97**:e12112.

29 Clarke JR, Trooskin SZ, Doshi PJ, Greenwald L, Mode CJ. Time to laparotomy for intra-abdominal bleeding from trauma does affect survival for delays up to 90 minutes. *The Journal of Trauma: Injury, Infection, and Critical Care* 2002;**52**:420–5.

30 MacDonald SL, Robinson LR. An evaluation of age-based differences in the demographic features and clinical outcomes of trauma rehabilitation patients. *American Journal of Physical Medicine & Rehabilitation* 2020;**99**:999–1003.

31 Earl-Royal E, Kaufman EJ, Hsu JY, Wiebe DJ, Reilly PM, Holena DN. Age and preexisting conditions as risk factors for severe adverse events and failure to rescue after injury. *Journal of Surgical Research* 2016;**205**:368–77.

32 Schoeneberg C, Schilling M, Hussmann B, Schmitz D, Lendemans S, Ruchholtz S. Preventable and potentially preventable deaths in severely injured patients: A retrospective analysis including patterns of errors. *European Journal of Trauma and Emergency Surgery* 2016;**43**:481–9.

33 Kleber C, Giesecke MT, Tsokos M, Haas NP, Buschmann CT. Trauma-related preventable deaths in berlin 2010: Need to change prehospital management strategies and trauma management education. *World Journal of Surgery* 2013;**37**:1154–61.

34 Davoodabadi A, Kashi EA, Mohammadzadeh M, Mousavi N, Shafagh S, Ghafoor L, *et al.* Predicting factors and incidence of preventable trauma induced mortality. *Annals of Medicine and Surgery* 2021;**68**:102609.