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**Opportunities for improvement in adult trauma patients admitted to the intensive care unit: A registry-based study**

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**Förbättringsmöjligheter i vården av vuxna traumapatienter som vårdats**

**på intensivvårdsavdelning: En register-baserad studie**

*Bakgrund:* Trauma är en ledande orsak till mortalitet och morbiditet i världen. En hörnsten i utvecklingen av förbättringsprogram för trauma är multidisciplinära mortalitets- och morbiditetskonferenser. Syftet med dessa är att identifiera förbättringsmöjligheter (OFI) i vården av traumapatienter. Många patienter med svårt trauma blir inlagda på intensivvårdsavdelning (IVA). Trots detta är kännedomen om OFI hos denna patientgrupp begränsad. Syftet med denna studie är att karaktärisera OFI hos vuxna traumapatienter som varit inlagda på IVA och bedöma hur patient- och processfaktorer är associerade med OFI hos denna patientgrupp. *Metod:* Detta är en registerbaserad studie som inkluderar traumapatienter från 2014 till 2023 som vårdats på Karolinska Universitetssjukhuset i Solna, varit inlagda på IVA och som har granskats avseende förekomsten av OFI vid en mortalitets- och morbiditetskonferens. Bivariabel och multivariabel logistisk regression användes för att bedöma sambandet mellan följande patient- och processfaktorer samt OFI bland denna patientgrupp: kön, ålder, om patienten var intuberad eller ej och hur många dagar, Revised Trauma Score (RTS), Injury Severity Score (ISS), jourtid vid ankomst till sjukhuset, tid från ankomst till sjukhuset till första datortomografi (DT), dagar på IVA, ASA-värde före trauma och överlevnad efter 30 dagar. *Resultat:* OFI identifierades hos 143 av 1449 patienter. Högre Revised Trauma Score (RTS) var associerat med högre odds för OFI, ≤ 7 dagar på intensivvårdsavdelningen (IVA) var associerat med lägre odds för OFI och död inom 30 dagar efter sjukhusvistelse var associerat med högre odds för OFI med statistisk signifikans i den ojusterade analysen. Högre Revised Trauma Score (RTS) var associerat med högre odds för OFI, och ≤ 7 dagar på IVA var associerat med lägre odds för OFI med statistisk signifikans i den justerade analysen. *Slutsats:* De patient- och processfaktorer som var signifikant associerade med OFI visade att högre RTS var associerat med högre odds för OFI och att ≤ 7 dagar på IVA var associerat med lägre odds för OFI.

**Opportunities for improvement in adult trauma patients admitted to the intensive care unit: A registry-based study**

*Background*: Trauma is a leading cause of mortality and morbidity worldwide. A cornerstone in developing the trauma quality improvement programs is multidisciplinary mortality and morbidity review. The purpose of these reviews is to identify opportunities for improvement (OFI), which are necessary to implement corrective actions. Many patients with severe trauma are admitted to the intensive care unit (ICU), but little is known about OFI in this group of patients. The aim of this study is to characterise OFI in adult trauma patients admitted to the ICU and assess how patient factors are associated with OFI in these patients. *Methods*: This was a registry-based study including all trauma patients between 2014 and 2023 from the Karolinska University Hospital in Solna who had been admitted to the ICU and who were reviewed regarding the presence of OFI by the mortality and morbidity conference. Bivariable and multivariable logistic regression were used to assess how the following patient and process factors were associated with OFI in this group of patients: gender, age, if the patient was intubated or not and how many days, Revised Trauma Score (RTS), Injury Severity Score (ISS), arrival outside of working hours, time from arrival at the hospital until first computed tomography (CT), days in the ICU, ASA preinjury and survival after 30 days. *Results*: OFI was identified in 143 of 1449 patients. In the unadjusted analysis, a higher RTS was significantly associated with higher odds of OFI (OR X-X, 95% CI X-X), ≤ 7 days in the intensive care unit (ICU) was significantly associated with lower odds of OFI, and death within 30 days after hospitalization was significantly associated with higher odds of OFI. In th adjusted analysis, higher Revised Trauma Score (RTS) remained significantly associated with higher odds of OFI, and ≤ 7 days in the ICU remained significantly associated with lower odds of OFI. *Conclusion*: The patient and process factors associated with OFI indicated that higher RTS was associated with higher odds of OFI, and ≤ 7 days in the ICU was associated with lower odds of OFI.

# Abbreviations

APACHE = Acute Physiology and Chronic Health Evaluation

ASA score = American Society of Anesthesiologists score

CT = computed tomography

GCS = Glasgow Coma Scale

GOS = Glasgow Outcome Score

ISS = Injury Severity Score

NISS = New Injury Severity Score

OFI = Opportunity For Improvement

RR = respiratory rate

RTS = Revised Trauma Score

SBP = systolic blood pressure

TRISS = Trauma and Injury Severity Score

# Introduction

Trauma — the clinical entity of injury and the body’s associated response — is a leading cause of mortality and morbidity worldwide. According to WHO, injury-related deaths constitute 8% of all deaths and take the lives of 4,4 million people yearly worldwide - more than HIV/AIDS, malaria, maternal mortality and tuberculosis combined. The top three out of five causes of death in people aged 5-29 are injury-related; road traffic injuries, homicide and suicide. Each year, tens of millions of people suffer non-fatal injuries leading to treatment at hospitals in emergency departments and acute care visits. These injuries often lead to temporary or permanent disability and the need for medical and mental rehabilitation. Trauma exposure at a young age increases the risk for mental illness and suicide leading to increased risk of an unhealthy lifestyle associated with smoking, alcohol and substance abuse, chronic disease and cancer as well as societal problems such as crime, poverty and violence. The burden of disease from injuries vary depending on certain conditions; socioeconomic factors, gender, age and country. Men suffer from injuries more often than women. Across all age groups worldwide, the top three leading causes of injury among males are road traffic injuries, homicide and suicide; whereas the top three leading causes of injury among women are road traffic injuries, falls and suicide (2).

According to the annual report from the Swedish Trauma registry (SweTrau) 2022, trauma was more common among men than women in Sweden — 65,3% men compared to 34,7% women. The most affected age group was the working population. The leading causes of trauma included; road traffic injuries, falls, weapons and stabs and blows. Previous years, road traffic injuries have been the leading cause of injury. However, since 2022 road traffic injuries and falls account for about the same proportion of mechanisms of injury. There are several variables that can be studied to assess primary patient care, for example time to first CT and acute interventions. Median time to first CT at the university hospitals of Sweden was 30 minutes in unconscious patients with GCS < 9. Acute interventions is defined as interventions performed immediately or within 24 hours after arrival to a hospital. The most common acute interventions in Swedish hospitals were: thoracic drains, wound revisions and fracture surgery followed by laparotomy with haemostasis, radiological interventions such as embolisation and stents, and thoracotomy (3).

Albaaj et al. recently analyzed opportunities for improvement (OFI) in relation to different patient and process factors based on a selection of data from SweTrau including the patients admitted to the Karolinska University Hospital in Solna following trauma. The study indicated that patients with moderate to severe trauma are at the highest odds of OFI (4). According to SweTrau 2022 41,1% of patients with New Injury Severity Score (NISS) > 15 who were at a university hospital were admitted to the ICU. The proportion of severely injured admitted to the ICU has decreased in recent years, however; patients with NISS > 15 still constitute a large proportion of the trauma patients treated in the ICU. A way to measure functional level after hospital discharge is Glasgow Outcome Scale (GOS). According to GOS, among patients with NISS > 15 17% were deceased, 20% suffered severe disability, 49% suffered moderate disability and 14% had good recovery in the university hospitals of Sweden (3).

For all injuries, quality hospital care can reduce the amount of short- and long-term disability. Therefore, improving planning, access and organization of trauma care systems, involving prevention, pre-hospital care, intra-hospital care rehabilitation as well research and quality improvement, all play a central role in reducing overall impact after trauma (1). Disability-adjusted life-years (DALYs) is a way to measure post-discharge quality of life. Trauma accounts for one-tenth of DALYs, most of the burden in low- and middle-income countries (LMIC) (6). Trauma costs approximately 3% of gross domestic product (GDP) yearly globally, as it mostly affects the working population (7).

## Trauma quality improvement programs

Many initiatives for quality improvement programs have been seen in trauma and critical care based on the paradigm of Donabedian (8), stating that implementing proven structures and processes of care is the most effective way to improve outcomes. One example of a structure and process intervention in the intensive care unit is highly-staffed ICUs that has been associated with improved outcomes, as well as bundles to recognize and treat common conditions such as those for treating sepsis and ventilator-associated pneumonia (9). The intention of quality improvement is objective improvement in regard to preventability. A cornerstone in developing the trauma quality improvement programs is multidisciplinary mortality and morbidity review. The purpose of these is to discuss preventable deaths and identifying OFIs in trauma care regarding structure as well as clinical processes. This way, identifying OFIs will provide guidance as to what to focus specific efforts on. There are several other methods to improve trauma care. However, mortality and morbidity review has been shown to be a key method of addressing all necessary components of trauma improvement (10).

Trauma audit filters are descriptions of specific actions that should be taken, time frames in which tests or treatments should be provided, or outcomes that are expected to occur in injured patients. Assessing patients whose care falls outside the frames of these audit filters and providing feedback to the clinicians involved in the patient’s care provides means of correcting errors and improving future trauma care. The audit filters were introduced by the American College of Surgeons 1995; however, they have been criticized as they may not be directly linked to meaningful clinical or patient-centered outcomes (11). At the Karolinska University Hospital in Solna local audit filters are used. These local audit filters include: systolic blood pressure under 90, GCS < 9 and not intubated, ISS > 15 but not admitted to the ICU, ISS > 15 and no trauma team activation, no anticoagulation treatment within 72 h after traumatic brain injury, time to acute intervention more than 60 minutes, time to CT more than 30 minutes, liver or spleen injury, cardiopulmonary resuscitation with thoracotomy, massive transfusion and death within 30 days after trauma.

## Injury score systems

When a patient first arrives at the hospital, injury score systems are used to assess how urgent the need of interventions to a patient is. There are several injury score systems: Injury Severity Score (ISS), New Injury Severity Score (NISS), Revised Trauma Score (RTS) and Trauma and Injury Severity Score (TRISS).

ISS is an anatomical scoring system providing an overall severity score for patients with multiple injuries. Each injury is assigned an abbreviated injury scale (AIS) score and is allocated to one of six body regions. The three most severely injured body regions have their scores squared and added together to produce an ISS score between 0 and 75. If an injury is assigned an AIS of 6 the ISS score is automatically assigned to 75. Major trauma is considered when ISS > 15. The major drawback of ISS is that it only considers one injury for each body region. Therefore, if several severe injuries are in the same body region, they are not accounted for. NISS counters the problem of ISS being the sum of the squares of the three most severe injuries, regardless of body region injured. NISS is therefore equal to or higher than ISS.

RTS is a physiological scoring system calculated from the patients vital signs; Glasgow Coma Scale (GCS), respiratory rate and systolic blood pressure. RTS is heavily weighted towards GCS compared to respiratory rate and systolic blood pressure. It has been demonstrated to show accuracy at predicting death. Each of the mentioned variables get a corresponding code value between 0 and 4 based on the value of GCS, RR and SBP. The formula for RTS is RTS = (0.9368 x GCS code value) + (0.7326 x SBP code value) + (0.2908 x RR code value) (12).

TRISS has a maximum prediction in outcome when compared with the other scores. The score determines the probability of survival based on a formula consisting of ISS, RTS and the patient’s age. TRISS is therefore both an anatomical and physiological scoring system (13).

## Classifications systems for patient’s general health

Another way to assess the state of a patient in addition to the injury score systems are classification systems for patient’s general health. Two of these are ASA score and APACHE II.

American Society of Anesthesiologists (ASA) classification was originally created to establish a scoring system for evaluation of a patient’s general health and comorbidities before an operative procedure (14). However, recent studies have also showed ASA class to be a significant predictor for length of stay, indicating that ASA score can be used as predictor in other aspects of hospital care as well (15).

Acute Physiology and Chronic Health Evaluation (APACHE) II is the most commonly used severity-of-disease scoring system in ICUs all around the world. The worst value for each physiological variabel is converted to an integer score from 0 to 71 within the first 24 hours of admittance. Higher score indicates more severe disease and higher risk for mortality. The score has not been validated for use on patient’s under 16 years of age. APACHE II has shown to be a good score for discriminating between survivors and non-survivors (16).

## Preventable deaths in patients admitted to the ICU

There are many studies on preventable deaths in trauma patients treated in the ICU both regarding the medical aspect as well as the human aspect. According to a study from Japan on the medical aspect, the primary medical causes of death after trauma are haemorrhage, sepsis/multiorgan failure and central nervous system injury. Delayed hemostatic procedures and transfusions were common areas for improvement in the hospital stage (17). The most prominent OFI in regard to haemorrhage was decision-making compared to errors in technical skill. The OFIs frequently involved the decision between radiology, surgery and further investigation (18).

A study from The University of Pennsylvania looked at the human aspect of OFIs in the ICU. The ICU of this hospital uses telemedicine and telemonitoring to review critical patient events. The areas of improvement they identified were: team dynamics and communication, use of best practices, increased and standardized access to emergency resources and improvement of procedural technique. They recommend other ICUs with telemedicine capacity to adopt a similar strategy in order to present OFIs and educational discussions (19). Another study looked at how critical information was handled in the ICU and found that laboratory values and test results were the most frequently lost items. This points at the importance of communication and handling of critical information at handoffs of care (20).

Preventability in studies is often defined as an event that would not have occurred had the patient received ordinary standards of care. Evaluating preventable deaths in patients admitted to the ICU can be a challenge as the patients have extensive medical history and it is harder to understand what the standard of care is for those patients. Furthermore, even though these patients receive the best of care, these patients still have a higher risk of developing complications or dying. Some might even be in such a bad condition that they die just when they have been admitted to the ICU from the ward or emergency care (9).

Many patients with severe trauma are admitted to the intensive care unit (ICU), but little is known about opportunities for improvement in this group of patients. This being due to the patients admitted to the ICU being more complex. Identifying OFIs in this group can therefore be more of a challenge. There are existing studies on different aspects of trauma care improvement, but studies focusing mainly on OFI in the ICU are few.

## Aim

The aim of this study is to characterise OFI in adult trauma patients admitted to the ICU and assess how patient and process factors are associated with OFI in these patients.

# Methods

## Study design

We conducted a retrospective single-centre cohort study based on data from the Karolinska University trauma registry, which is part of the the Swedish Trauma registry and the Karolinska trauma care quality database. We used R for all statistical analyses (21).

For patients where hospital values for systolic blood pressure, respiratory rate or GCS score were missing from the emergency department, prehospital values were used instead. If the patient was intubated we automatically assumed that GCS was equal to 3 and RR was equal to 0. For the RTS-variable, each of the variables GCS, SBP and RR were then converted to a RTS-code between 0 and 4 based on what the values of GCS, SBP and RR were respectively. RTS was then calculated using the formula for RTS based on the combination of the RTS-codes assigned to each of the previously listed variables.

A complete case analysis was conducted after handling missing values. We present sample characteristics using descriptive statistics.

## Setting

The Karolinska University Hospital in Solna is a level 1 equivalent trauma centre based on the definition by the American College of Surgeons (ACS) Committee on Trauma (22), which means that all patients in Stockholm with severe or suspected severe trauma are sent there. The hospital has direct access to radiology, surgery, emergency medicine, intensive care and consultants from relevant specialities (23). All patients are included in a mortality and morbidity screening process, combining audit filters and an individual review by specialized nurses. The patients who are identified as having higher probability for OFI are discussed in a multidisciplinary conference held every 6-8 weeks. Examples of OFI include the need for better organization or more senior members taking part in the trauma care. The presence or absence of OFI is decided among the participants of the conference and then recorded in the trauma care quality database.

## Participants

The trauma registry includes all patients admitted with trauma team activation, regardless of Injury Severity Score (ISS), as well as patients admitted without trauma team activation but found to have an ISS of more than 9. We included all patients who had been included in the morbidity and mortality screening process between January 1, 2014 and February 1, 2023 and who were also admitted to the ICU. We excluded patients who were younger than 15 years and patients who were dead on arrival.

## Variables and data sources/measurements

### Study outcome

The study outcome is the presence of OFI – defined as “Yes” at least one identifies OFI, or “No” identified OFI – through consensus from the mortality and morbidity conference.

### Patient and process factors

The variables were factors chosen from the trauma registry, based on the locally used audit filters, standard epidemiological factors and factors registered in the Swedish Trauma registry. The categorical factors were sex, age, if the patient was intubated or not and how many days, Revised Trauma Score (RTS), Injury Severity Score (ISS), on call, time from arrival at the hospital until first computed tomography (CT), days in the ICU, ASA preinjury and survival after 30 days. On duty was defined as before 8.00 a.m., after 5 p.m., or during a weekend - defined as Saturday or Sunday.

## Study size

There were 14,022 patients in the trauma registry between January 1 2013 and February 1 2023. 2679 of these patients were admitted to the ICU. 3 patients were then excluded as they were younger than 15 years and 6 patients were excluded because they were dead on arrival. 928 patients were excluded because there was no registration on whether there was an OFI or not. 293 patients were excluded because they had missing values in one or more variables. This leaves us with 143 outcomes for OFI, and 1,306 outcomes for “No OFI”.

## Statistical methods

Bivariable logistic regression was used to determine unadjusted associations and multivariable logistic regression to determine adjusted associations between patient and process factors and OFI. Odds ratios (OR) with associated 95% confidence intervals was used with a 5% significance level.

## Ethical considerations

There are several ethical aspects to take into consideration regarding this study: voluntary participation, informed consent, anonymity, confidentiality, potential for harm and results communication.

As described previously, all patients with trauma team activation or high ISS scores are included in the database used for this study. Having suffered severe trauma might not be something the patients or their relatives would want to be public information as the collected data contain for instance vital parameters and demise as well as type of trauma and time of arrival to the hospital, which might be sensitive information. Therefore, the ethical aspect of voluntary participation and informed consent has to be considered. The data in national databases is collected from all patients registered and is not based on consent, even though it might be informed, which is a drawback.

To respect the anonymity and confidentiality aspect the statistical analysis was first conducted on synthetic data and later implemented on the data collected from the trauma registry and the trauma care quality database in order to protect personal numbers and their associated information. The anonymity might ease the discomfort among the involved patients and their relatives.

There is no direct potential for harm by being included in the study as no intervention is made and it is an observational study.

In regard to results communication, the results from research based on the data as well as a compilation of the original data is public. The data being accessible for research does not directly benefit the affected individual; however, it contributes greatly to the development of the hospital care in Sweden, making it more efficient and equal. Studies performed on data from the Karolinska University Hospital in Solna are made to improve local trauma care systems. This way, it can also benefit the society as improved local trauma care decreases trauma death rate and improves quality of care and thus patient safety.

Based on these arguments it can be concluded that the advantages outweigh the disadvantages. The advantages being the contribution to the development of trauma systems which long-term improves patient safety and equality, and that the study protects the individual’s anonymity and confidentiality by using synthetic data and later implementing it on the real data. The disadvantage being the potential emotional harm from the absence of voluntary participation.

The study was approved by the Swedish Ethical Review Authority, approval numbers 2023-02975-02, 2021-03531, 2021-02541.

# Results

## Participants

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Automatiskt genererad beskrivning

14,022 patients were included in the trauma registry and trauma care quality database between 2017 and 2023, out of which 12,278 patients were excluded, leaving 1,742 patients eligible for the study. 11,343 were excluded because they were not treated in the ICU. Three patients were excluded because they were under 15 years old. 6 patients were excluded because they were dead on arrival, and 928 patients were excluded because there was no data on the presence or absence OFI. 293 patients were excluded because there was missing data, leaving a total of 1,449 patients included in the study.

## Descriptive data

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Automatiskt genererad beskrivning**

**Table 1** present sample characteristics. 1,096 (76%) patients were male and 353 (24%) patients were female. 846 (58%) patients were not intubation, 241 (17%) patients were intubated for 1-7 days and 113 (7,8%) patients were intubated for more than 7 days. The number of patients who arrived outside working hours — on Saturday or Sunday or after 5 pm or before 8 am were 1,042 (72%). 1,064 (73%) patients were equal to or less than 7 days in the ICU, and 385 (27%) patients were more than 7 days in the ICU. 1,080 (75%) patients had an ASA-score of 1-2 before arrival to the hospital, and 369 (25%) patients had an ASA-score of 3-7 before arrival to the hospital. 286 (20%) patients died within 30 days after hospitalization.

## Main results

**Table 2**. Unadjusted and adjusted logistic regression analyses of associations between patient level factors and opportunities for improvement.

| **Characteristic** | **N** | **OR** | **95% CI** | **p-value** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sex** | 1,742 |  |  |  |  |  |  |
| Female |  | — | — |  | — | — |  |
| Male |  | 1.27 | 0.87, 1.91 | 0.2 | 1.21 | 0.80, 1.90 | 0.4 |
| **Age** | 1,742 | 1.00 | 1.00, 1.01 | 0.5 | 1.01 | 1.00, 1.02 | 0.2 |
| **Intubation** | 1,742 |  |  |  |  |  |  |
| No intubation |  | — | — |  | — | — |  |
| Intubation 1-7 days |  | 1.37 | 0.86, 2.14 | 0.2 | 1.30 | 0.78, 2.13 | 0.3 |
| Intubation > 7 days |  | 0.83 | 0.36, 1.67 | 0.6 | 0.68 | 0.26, 1.52 | 0.4 |
| Unknown |  | 0.96 | 0.67, 1.37 | 0.8 | 1.04 | 0.69, 1.57 | 0.8 |
| **Revised Trauma Score** | 1,535 | 1.18 | 1.08, 1.30 | **<0.001** | 1.22 | 1.10, 1.36 | **<0.001** |
| **ISS** | 1,741 | 1.00 | 0.99, 1.01 | 0.9 | 1.01 | 0.99, 1.02 | 0.3 |
| **Time to first CT** | 1,632 | 1.00 | 1.00, 1.00 | 0.3 | 1.00 | 1.00, 1.00 | 0.3 |
| **On duty** | 1,742 | 1.05 | 0.74, 1.52 | 0.8 |  |  |  |
| **Days in the ICU** | 1,738 |  |  |  |  |  |  |
| > 7 days |  | — | — |  | — | — |  |
| ≤ 7 days |  | 0.66 | 0.47, 0.93 | **0.015** | 0.55 | 0.36, 0.82 | **0.004** |
| **ASA preinjury** | 1,735 |  |  |  |  |  |  |
| ASA 1-2 |  | — | — |  | — | — |  |
| ASA 3-7 |  | 1.20 | 0.84, 1.69 | 0.3 | 1.23 | 0.77, 1.94 | 0.4 |
| **Survival** | 1,739 |  |  |  |  |  |  |
| Alive |  | — | — |  | — | — |  |
| Dead |  | 0.60 | 0.37, 0.93 | **0.030** | 0.54 | 0.29, 0.98 | **0.049** |
| **OnDuty** |  |  |  |  | 1.03 | 0.70, 1.55 | 0.9 |

**Table 2** shows the unadjusted and adjusted associations of the selected patient and process factors in relation to OFI. In the unadjusted analysis the factors that were significantly associated with the presence of OFI were: Revised Trauma Score 1.18 (95% CI 1.08, 1.30; p<0.001), ≤ 7 days in the ICU 0.66 (95% CI 0.47, 0.93; p=0.015) and death within 30 days after hospitalization 0.60 (95% CI 0.37, 0.93; p=0.030).

In the adjusted analysis the following factors demonstrated significant association with OFI: Revised Trauma Score 1.22 (95% CI 1.10, 1.36; p<0.001) and ≤ 7 days in the ICU 0.55 (95% CI 0.36, 0.82; p=0.004).

RTS was significantly associated with increased odds of OFI in both the unadjusted and adjusted analyses. ≤ 7 days in the ICU was significantly associated with decreasing odds of OFI in both the unadjusted and adjusted analyses.

Sex, Age, Intubation, ISS, time to first CT, on duty and ASA preinjury were not significantly associated with OFI in the unadjusted nor the adjusted analyses. Female sex, intubation > 7 days, > 7 days in the ICU, ASA preinjury 1-2 and survival 30 days after hospitalisation could not be analysed with logistic regression.

**Table 3**. Unadjusted and adjusted logistic regression analyses of associations between patient level factors and opportunities for improvement in patients alive 30 days after hospitalization

| **Characteristic** | **N** | **OR** | **95% CI** | **p-value** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sex** | 1,395 |  |  |  |  |  |  |
| Female |  | — | — |  | — | — |  |
| Male |  | 1.32 | 0.87, 2.07 | 0.2 | 1.20 | 0.74, 2.00 | 0.5 |
| **Age** | 1,395 | 1.01 | 1.00, 1.02 | 0.14 | 1.01 | 0.99, 1.02 | 0.4 |
| **Intubation** | 1,055 |  |  |  |  |  |  |
| Intubation > 7 days |  | — | — |  | — | — |  |
| Intubation 1-7 days |  | 0.93 | 0.40, 2.21 | 0.9 | 1.62 | 0.60, 4.39 | 0.3 |
| No intubation |  | 1.25 | 0.68, 2.55 | 0.5 | 1.51 | 0.56, 4.09 | 0.4 |
| **Revised Trauma Score** | 1,228 | 1.09 | 0.99, 1.21 | 0.094 | 1.10 | 0.91, 1.35 | 0.4 |
| **ISS** | 1,394 | 1.01 | 1.00, 1.02 | 0.2 | 1.01 | 1.00, 1.03 | 0.2 |
| **Time to first CT** | 1,304 | 1.00 | 1.00, 1.00 | **0.037** | 1.00 | 1.00, 1.00 | 0.7 |
| **On duty** | 1,395 | 1.05 | 0.72, 1.57 | 0.8 |  |  |  |
| **Days in the ICU** | 1,394 |  |  |  |  |  |  |
| > 7 days |  | — | — |  | — | — |  |
| ≤ 7 days |  | 0.81 | 0.56, 1.18 | 0.3 | 0.60 | 0.36, 1.01 | 0.051 |
| **ASA preinjury** | 1,392 |  |  |  |  |  |  |
| ASA 1-2 |  | — | — |  | — | — |  |
| ASA 3-7 |  | 1.18 | 0.79, 1.74 | 0.4 | 1.22 | 0.70, 2.09 | 0.5 |
| **OnDuty** |  |  |  |  | 1.09 | 0.70, 1.75 | 0.7 |

**Table 3** shows the unadjusted and adjusted associations of OFI and the selected patient and process factors among the patients who were alive 30 days after hospitalization. In the unadjusted analysis time to first CT 1.00 (95% CI 1.00, 1.00; p=0.011) was significant. Indicating that it has no correlation with increasing or decreasing odds of OFI.

# Discussion

The key results from this study are that we found that higher RTS was associated with higher odds of OFI, ≤ 7 days in the ICU was associated with decreased risk of OFI. Age, sex, intubation, ISS, time to first CT, on duty and ASA preinjury were not significantly associated with OFI in neither the unadjusted or the adjusted analyses. In the subgroup analysis of patients who were alive 30 days after hospitalization no patient or process factor was significantly associated with OFI.

We found that higher RTS was associated with higher odds of OFI. RTS is a combined value of systolic blood pressure, Glasgow Coma Scale and respiratory rate with more weight towards GCS. An explanation for the increased odds of OFI in patients with increased RTS could be that the patients with low RTS values - with low GCS, RR and SBP also are the ones that are in a bad state upon arrival — upon which emergency procedures e.g. intubation have been carried out rapidly due to the patients being visibly ill from the beginning. The patients who are being missed and where certain procedures take longer time before being performed are the patients who seem stable upon arrival, but who later become worse — the patients with comparatively higher RTS scores. In Albaaj’s study respiratory rate >29, systolic blood pressure 50-75 mmHg and 76-89 mmHg, and Glasgow Coma Scale 9-12 were significantly related to increased odds of OFI in the unadjusted analysis, but not in the adjusted analysis among patients from the part of the Swedish Trauma Registry covering patients from the Karolinska University Hospital in Solna (13). All of these variables equal medium to higher RTS values — capturing the group of patients who’s vital parameters are negatively affected by the trauma, but who are relatively stable in the group of trauma patients. This creates a sense of false security, leading to increased time until necessary emergency procedures are performed.

The variable ≤ 7 days in the ICU was significantly associated with decreasing odds of OFI in both the adjusted and unadjusted analyses. There are two aspects to consider concerning this variable. One aspect would be that less days spent in the ICU compared to more days spent in the ICU indicates that patients have been in a better state and needed less time of recovery before leaving the hospital. Furthermore, a longer stay leads to more space for mistakes being made. The other aspect of the variable would be that few days in the ICU could indicate the patient passing away before any mistakes having been made due to the patient being very ill from the beginning — cases in which the deaths were not preventable, but rather expected.

Previous studies have shown that prolonged ICU stay is a risk factor for increased mortality and morbidity in trauma patients (25). Something to consider is the reason for the lengthened stay in the ICU. Studies have shown that patient characteristics on admission, like comorbidities, age and severity of illness do not fully explain the increased long-term mortality. With lengthened stay in the ICU the reason for stay in the ICU become increasingly less associated with patient’s original reason for admittance and increasingly associated with persistent chronic illness with associated organ dysfunction (27). This being the case, this might be an explanation for the lack of sigificance for ASA preinjury and ISS in the analysis. As stated above severity of illness and comorbidities do not fully explain increased long-term mortality. OFI may therefore not correlate fully with ASA preinjury and ISS respectively which are factors describing comorbidities and the severity of illness.

However, a retrospective cohort has shown that lower admission illness severity and younger age were associated with earlier discharge and therefore less associated with persistent critical illness, which would then indicate a stronger association between ISS and ASA preinjury to length of stay in the ICU as the patients who are in a better state leave the hospital earlier and there is less odds for OFI. On the other hand, the cohort also showed that lower comorbidity was associated with persistent critical illness rather than early discharge from the ICU — supporting the opposite side of the argument (28).

Several studies have also studied the association between different factors that affect the length of stay in the ICU. Associations between hypoglycaemia, use of any corticosteroids, use of any neuromuscular agents, use of any benzodiazepines for more than 1 day, the need for mechanical ventilation for > 2 days, initiation of new dialysis and the occurrence of new infection has been found to have a correlation to increased total and 5-year mortality (26). An association between bleeding in patients and increased length of stay in the ICU has also been found (29).

Death within 30 days after hospitalization was associated with OFI in the unadjusted analysis but not in the adjusted analysis. Patients who died within 30 days after hospitalization could either have suffered a severe trauma or have been in a poor state from the beginning; therefore increasing the odds of OFI.

Sex and age were not significant in the unadjusted nor the adjusted analyses, which implicates that the patients were not treated differently based on age or gender. There are many studies on gender in association to health care. It has previously been shown that there is no difference in willingness to admit to the ICU between cases describing a man or woman in the physician’s responses (30). However, studies also show that, among severely injured patients, female gender is associated with lower in-hospital mortality among those aged 16-44 years. Female gender is also associated with decreased likelihood for ICU admission (31). Male gender contributes more to poor outcomes in postoperative ICU patients, and two-thirds of ICU resources are consumed by male patients (32). However, in our study we could not see any correlation between OFI and one specific gender in the occurrence of OFI. Although we can also see that the majority of the patients included in this study were also males. There is possibly a reason for higher admittance of males to the ICU and association with poorer outcomes, but it has nothing to do with odds of OFI.

ASA preinjury was not significant in the unadjusted nor the adjusted analyses. Preinjury ASA score has been shown to be a reliable score for predicting mortality after trauma, predicting readmission after traumatic injury and for classifying comorbidity in trauma patients (35). ASA score was originally developed to assess a patient’s health before surgical procedures and therefore provided information on how much risk for postoperative complications there was. Studies have investigated if ASA score also is a good predictor in other aspects of medical care and as discussed above it is a predictor for mortality after trauma and for readmission. However, this does not automatically mean that there is an correlation between ASA score and OFI. Patient’s with higher ASA scores might receive more attention when admitted to the ICU due to their comorbidities, but as the variable used in this study is ASA preinjury — a measurement of the patient’s health before the trauma — this might not contribute to a fair picture of the current state of the patient, which injury scores like RTS might.

The variable on duty was not significant in either analyses indicating that the time of arrival of the patients did not affect their medical treatment. Trying to reduce number of OFI can therefore not be solved by increasing medical resources outside working hours. On-call sleeping has been studied and it has been stated that sleeping between calls is beneficial for waking performance. However, there might be a temporary increase in performance impairment that should be taken into consideration (36).

Something to consider is why ISS was not significant in the analyses. Patients admitted to the ICU are usually in a bad shape with generally high ISS. ISS is based on the square of the three highest AIS scores allocated to the three most severly injured body parts. The downside of ISS on its own is that it has higher predictive value when combined with other parameters like vital signs, comorbidities and mechanism of injury. ISS is an anatomical model, compared to RTS which is a physiological model. Among trauma patients admitted to the ICU the physiological models perform better than the anatomical models. However, patients with low scores in the physiological model also require an anatomic analysis of the injuries to determine their severity (37). NISS has been found to be better than ISS in predicting the ICU admission of trauma patients, as well as for predicting prolonged ICU length of stay (38). This could be an explanation to why ISS is not significant in the results of this analysis, as RTS as well as NISS are potentially better models for patients admitted to the ICU.

## Strengths and limitations

One of the strengths of this study is that it is a registry-based study which means that the quality of the data is reliable. The collection of the included variables were pre-defined which means the reporting of the included variables was standardized. Furthermore, the specific inclusion criteria of the study: including patients 15 years and older, who were not dead on arrival and who were admitted to the ICU, resulted in a specific and well-defined cohort. This contributes to the reliability and reproducibility of the study.

There were several limitations to our study: the limited study size, the selection of patients for the morbidity and mortality review and the definition and use of the physiological variables of the study.

Firstly, the study size was limited. This was a single-centre study and illustrate the situation at the Karolinska Intitute Hospital in Solna. Due to the small cohort of this study, it limits the applicability of this study to other level 1 trauma centers and ICUs. The small cohort might also affect the accuracy of the results.

Secondly, the selection of patients for the morbidity and mortality review relied mostly on the local audit filters used at the Karolinska Institute Hospital in Solna. Using audit filters to select patients for the conference is associated with high false positive rates, ranging from 24% to 80% (39). Even though the use of audit filters is associated with high false positive rates, there is still a risk of misplacement where some patients with OFI were not selected by for the review based on the audit filters although there was an OFI that occurred later on during the hospital stay.

The definition of the RTS-value is a combination of GCS, SBP and RR. The variables used were the values from the emergency department. When these were missing, the prehospital values were used. If these were also missing, but there was documentation indicating that the patients had been intubated, we replaced GCS and RR with a value of 0. This is motivated for due to patients not breathing or being conscious when intubated. The acquired values were then combined to calculate a value for RTS. If the patient had missing values for either one of GCS, SBP or RR they were excluded from the study. The handling of these variables and their combination to RTS could affect the result as the values used are from either prehospital values, emergency department values or from identification of intubation. This could potentially affect the accuracy of the data and decrease the possibility for reproducibility. However, one could also argue that as the RTS value is a combined score of 3 physiological variables the combination of them decreases the overall inaccuracy and produces a satisfactory measurement of the physiological state of the patient.

## Generalizability

The study is conducted on 143 outcomes of OFI. There were few outcomes because we included only those who were admitted to the ICU, > 14 years old, not dead on arrival and had a registration for the presence or absence of OFI. The external validity is therefore compromised due to the limited size of the study. The internal validity is however high thanks to the well-defined cohort specifying trauma patients admitted to the ICU at the Karolinska University Hospital in Solna. The results from this study is therefore highly relevant for understanding where further efforts for trauma improvement should be directed among ICU trauma patients at this hospital.

## Clinical applications

The potential clinical application for this study is to further contribute to the development of improved trauma care. Identifying the group of patients admitted to the ICU is another step in the direction of identifying the patients who would benefit the most from further improvements in trauma care. Trauma has a great global impact and this study amongst others on the subject all contribute to the more specified efforts in trauma quality improvement systems. Additionally, this study has offered further insights to the patient profile of the trauma center at Karolinska University Hospital in Solna admitted to the ICU.

## Future studies

More research is needed on the area of OFI in patients admitted to the ICU. The most relevant limitation of this study was the limited study size. A suggestion would be to conduct a multi-centre study, covering larger databases or combining several databases, on this group of patients to further investigate areas for improvement and to further contribute to the improvement of trauma quality programs.

Based on the results from this study, variables of interest for future studies could be number of days in the ICU and investigation of GCS, RR and SBP separately instead of them as a combined RTS-score. It would be interesting to see if one of the vital parameters is better for predicting OFI than the others in a larger cohort.

Based on the statistical significance for higher RTS being associated with higher odds of OFI, efforts should be more focused towards trauma patients who are relatively stable upon arrival, but who have a risk of getting worse. Future studies should investigate what factors that could potentially indicate eventual worsening of the state of the patient. Focusing on patients who are stable upon arrival overall is very extensive, which further emphasizes the importance of identifying such variables.

ASA preinjury did not show any correlation with OFI in this study. However, it would be interesting to further investigate the correlation between ASA preinjury or another scoring system of the patient’s general health before admittance to the hospital, and a combined physiological and anatomical injury scoring system to see if they predict OFI better combined than separately.

# Conclusion

The aim of this study was to characterize patient and process factors among adult patients admitted to the ICU that were associated with OFI. The study showed that higher RTS score is associated with increased odds of OFI indicating that patients who are relatively well upon arrival to the hospital are the group where improved trauma care should get more focus than they do now. The logistical regression also showed that ≤ 7 days in the ICU was associated with decreased odds of OFI indicating that patients who are at the hospital less days in the ICU compared to more days in the ICU are less prone to opportunities for improvement.

# Contributions

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