Associations between emergency procedures and opportunities for improvement in adult trauma patients

## List of Abbreviations

* DALY – Disability-Adjusted Life Years
* HIC – High-income countries
* ISS - Injury Severity Score
* KUH - Karolinska University Hospital
* LMICs - Low- and Middle-Income Countries
* M&M - Morbidity and Mortality
* OFI - Opportunities For Improvement
* TQIP – Trauma quality improvement programs
* WHO - World Health Organization

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# Introduction

## Background

### Trauma

Trauma, a condition resulting from physical injury and the body’s associated response (1), is a significant cause of death and permanent disability worldwide. In 2020, the world health organization (WHO) estimated that trauma resulted in about 4.4 million deaths, constituting approximately 8% of all deaths globally (2). The treatment and rehabilitation of trauma patients require a multidisciplinary approach, resulting in considerable public health care burdens and substantial personal, societal, and economic costs. Road injuries alone are estimated to cost the global economy US$1.8 trillion in 2015–30. These costs are equivalent to 0.12% of an annual tax on global domestic products (3). According to WHO, the primary causes of trauma include road traffic injuries, interpersonal violence, suicide, drowning, and fall accidents (2). Road injuries are the leading contributor to disability and death among adults, accounting for over 26% of all Disability-Adjusted Life Years (DALYs) in 2019, which measure the disease burden as the number of years lost due to ill health, disability, or death. In comparison, interpersonal violence is more common among young adults and contributes to approximately 14% of DALYs due to trauma. Lastly, fall accidents are common in older people and rank among the top ten causes of DALYs for individuals aged seventy-five and above (4).

### Trauma care globally

Trauma care varies significantly worldwide, with notable differences in low- and middle-income countries (LMICs) which account for 90% of trauma-related deaths and bear the highest burden of DALYs lost (5,6).

In contrast, high-income countries (HIC) have well-established trauma systems with specialized centers, trauma teams, high-quality treatment, and transportation protocols. This system manages the entire patient pathway, from the point of trauma, pre-hospital care, emergency department resuscitation, specialist emergency surgical intervention, and rehabilitation until the patient is reintegrated into society (9). Key elements of a trauma system include trauma centers, prehospital care, and quality improvement programs to provide appropriate services across the entire spectrum of trauma care (10).

### Trauma centers

Trauma centers are specialized hospital units that are equipped and staffed with experienced medical professionals to provide multidisciplinary advanced trauma care.. Trauma centers are associated with better patient outcomes, particularly for those suffering from severe injuries (10,12). The Injury Severity Score (ISS) is a widely used scoring system that estimates the severity of trauma on a scale from 1 to 75 (13). Research has shown that verified trauma centers can decrease the mortality risk by over 70% for patients with an ISS of 50 or higher (14). Trauma center verification is an independent benchmarking process to evaluate and improve the care for trauma patients (9)

### Trauma quality improvement programs

The WHO, the International Association for Trauma Surgery and Intensive Care, and the International Society of Surgery published joint Trauma Quality Improvement (TQI) guidelines in 2009 (15). The guidelines advocate conducting Morbidity and Mortality (M&M) conferences, which are designed to analyze patient cases and identify areas for improvement in the trauma care process. These conferences bring together all paramedical and medical specialties involved in pre-hospital and in-hospital trauma care to review patient cases, identify errors, and discuss means to improve patient trauma management. Data collected during the conference is recorded in a registry for further evaluation and analysis.

### Trauma Care in Sweden

Sweden has a well-established trauma system with 49 hospitals equipped to handle trauma patients with round-the-clock access to medical services, including surgery, anesthesia, and radiology. In addition, there are seven specialized trauma centers, one of which is a level 1 trauma center. These trauma centers are supported by a network of prehospital medical professionals and emergency services, including helicopter-based transport to trauma centers (16).

All emergency hospitals are affiliated with SweTrau, the only nationwide trauma database in the country. They register treated trauma patients using input variables selected through a European consensus effort in 2009. This effort involved experts from Scandinavia, the United Kingdom, Germany, and Italy, aiming to standardize data collection for cross-country trauma care analysis (17). SweTrau has been operational since 2011 and serves as a resource for systematically aggregating data and evaluating trauma care. In 2021 the national coverage rate for reported trauma cases reached 77% (18).

### Opportunities for improvement (OFI)

The Opportunity for Improvement (OFI) is an indicator commonly used within TQIPs to identify areas that can benefit from improved trauma care delivery (15). OFIs have been found at both system and personnel levels. These include errors in judgment, delayed or inappropriate treatment, and procedural errors (19–21).

Immediate trauma assessment requires a broad series of interventions to quickly identify and address the patient’s injuries. The type and severity of the trauma and the patient’s specific needs determine the range of necessary interventions (12). OFIs are frequently found during this phase of patient care (22,23).

OFIs in the emergency department are common in relation to surgical decision-making, resuscitation, and pre-hospital care. O’Reilly et al. found that problems with judgment are more common than those of skill and that implementing a systematic TQI system will reduce the mortality rate. They found 150 OFIs in 84 (66%) out of 127 patients (22).

Roy et al. (2017) found absence of surgical protocols, protocol deviation, pre-hospital delays, and delays in imaging constituted a significant contributor to system-level OFIs in urban Indian trauma care (24). Similarly, Sanddal et al. (2011) found that OFIs in Utah trauma care included lack of documentation, documentation errors, inadequate personnel training, and sub-optimal organization of resources (25).

### The presence of OFIs in risk patient groups

OFIs are more common in certain risk patient groups, such as the elderly population, who often have a high burden of comorbidities and limited physiological reserve. Hence, elderly patients might have impaired physical conditions to achieve successful trauma resuscitation. Obese patients and those with pre-existing medical conditions constitute a high-risk group as they may need more manpower and multidisciplinary medical resources. (25,26).

**Improving Trauma Care**

Immediate and correct interventions during resuscitation are essential, with a significant impact on patient outcomes. The aim of initial trauma care assessment is to stabilize the patient and preserve vital organ functions (12). It is known that the leading cause of OFIs is human errors during emergency initial care. (22–24,27–29).

Despite common global trauma TQI guidelines, there are differences in how TQI is measured around the world, mainly due to the use of different TQI indicators and lack of standardized TQI measurement registration. Hence, to obtain comparable data globally, it is suggested that creating an international trauma registry is important to find areas with potential for improvement of trauma care. The OFI is one of the indicators of TQI. However, there is limited data about the presence and patterns of OFI in relation to the resuscitation process and patient outcomes.

# Aim

The aim of this study was to assess how emergency procedures are associated with OFIs in trauma care.

# Methods

### Study design

We conducted a registry-based study using two registries: the Karolinska University Hospital (KUH) trauma care quality database and the Swedish national trauma registry, SweTrau. The trauma registry reports to the national trauma registry, including demographics, pre-hospital, hospital, and post-hospital care information, following the Utstein template (30). The trauma care quality database has patient-related information on OFI. Data from these two databases were merged and analyzed to estimate the association between the emergency procedures and OFIs using multivariable logistic regression.

### Setting

Karolinska University Hospital is in Stockholm, Sweden, and constitutes the trauma center for the Stockholm, Gotland, Västmanland, and Sörmland regions. This means that KUH is the main center for treating trauma for approximately 3 million people. The trauma center at KUH meets the standards of a level 1 trauma center defined by the American College of Surgeons (16,31). All high-priority trauma patients in Stockholm are transported to KUH for initial trauma assessment and treatment.

All patients treated at KUH were recorded in the Swedish national trauma registry. The inclusion of patient cases in the trauma care quality database was linked to the recording of patient cases in the Swedish national trauma registry. A specialized nurse assessed each patient case during registration, flagging cases suspected of having OFI. To assist the selection process, all cases were passed through a digital-based audit filter that identified cases based on a specific set of predetermined audit criteria, listed below, and automatically flagged selected cases. Subsequently, two specialized nurses assessed the flagged cases to determine if inclusion for M&M was appropriate. Patient cases with mortality as an outcome were directly included in the M&M review. Information on the cases discussed at the M&M conference was registered in the trauma care quality database with the notation OFI. (Figure 1)

### Flowchart describing the exclusions made and the process of trauma cases from arrival until OFI decision.

**Figure 1.** Flowchart describing the exclusions made and the process of trauma cases from arrival until OFI decision.

### Participants

Patients had to be recorded in the trauma registry and the trauma care quality database for inclusion. They also had to be 15 years or older, as the clinical management of children can differ significantly from that of adults.

The trauma registry includes patients who either met the criteria for a trauma team activation at the hospital or were admitted without activation but had an Injury Severity Score (ISS) over 9.

The trauma care quality database includes all patients reviewed by the M&M board. After collecting data on patients registered between 2017 and 2021, we conducted a complete case analysis for all patients discussed (n=6310) at M&M conferences, which involved excluding any patients with missing data in either the outcome variable, the covariates, or the independent variables.

### Variables

***Study outcome***

The study’s primary endpoint is OFI, a binary variable of “Yes” or “No”. The outcome is “Yes” if at least one OFI is found or “No” if no OFIs are identified.

***Exposures***

Exposures are the major surgical intervention or treatment performed within 24 hours of arrival at the hospital during trauma care, including thoracotomy, laparotomy, pelvic packing, revascularization, radiological intervention, craniotomy, intracranial pressure measurement, thoracic drain, external fracture fixation, major fracture surgery, and wound revision.

***Potential confounders***

Gender, age, blood pressure, respiratory rate, Glasgow Coma Scale (GCS), and ISS are considered confounding factors.

### Bias

Bias is avoided by using synthetic data during the development of the analysis model, which is later implemented on real patient data.

### Statistical analysis

The data was compiled and analyzed using the statistical computing language R (32). The variables were converted and handled according to the SweTrau manual (33). Descriptive statistics were used to describe the study sample. Multivariable logistic regression was conducted to estimate the associations between emergency procedures (independent variable) and OFIs (dependent variable). The results were presented with a 95% confidence level, and a p-value less than 0.05 was considered significant.

### Ethical considerations

***Respect for autonomy***

The information used in this study was collected from the SweTrau database (33). Patients were informed about their participation and were notified via letter that their data could be used in research. The patients have the right to be excluded from the database and can withdraw their participation at any time. To prevent the risk of a data breach, the patient information is stored in a secure database where patient names and ID numbers are fully anonymized.

***The Principle of Justice***

The inclusion criteria for the study are based solely on the nature of the patient’s condition and are not affected by any demographic or background factors. This approach ensures that the study results will be applicable to a broad population and that no patient groups will be excluded based on non-medical or scientific reasons.

***The Principle of Beneficence***

By identifying areas for improvement in emergency procedures, we can implement changes that will ultimately reduce mortality and morbidity among future trauma patients. Moreover, it might result in improving patients care, reducing trauma care burden on the public health system and health care costs.

***The Principle of Non-maleficence***

This is a retrospective study using an existing patient database and does not involve or alter any treatment or intervention. Hence, the patients are not exposed to any harm. With authorized individual access to the database and the data by anonymized and securely stored patient data, the risk of data misuse and leakage of patient data is minimal.

***Ethical permit***

Stockholm Research Ethics Review Board approves the study with approval reference numbers: 2021-02541 and 2021-03531.

# Results

### Patient Characteristics

The study included 6310 patients. Patient characteristics are summarized in Table 1. The study population consists of 4383 (69.5%) males and 1927 (30.5%) females, with a median age (min, max) of 43.0 [15.0, 100]. The mean value of ISS for all patients was 12.4, with a median value of 9. The mean value for respiratory rate was 18.4 breaths per minute, and for GCS it was 14.1. The mean value for systolic blood pressure was 133 mmHg. Craniotomy (n=235, 3.7%), surgical wound revision (n=309, 4.9%), and major fracture surgery (n=235, 3.7%) were the most common interventions. The mortality rate within 30 days after trauma was 9.5% (n = 599).

**Table 1. Patients’ characteristics in relation to the presence of OFI**

|  |  |  |  |
| --- | --- | --- | --- |
|  | OFI | No OFI | Overall |
|  | (N=431) | (N=5879) | (N=6310) |
| Age |  |  |  |
| Mean (SD) | 48.1 (21.2) | 44.9 (21.2) | 45.2 (21.2) |
| Median [Min, Max] | 47.0 [15.0, 97.0] | 42.0 [15.0, 100] | 43.0 [15.0, 100] |
| Gender |  |  |  |
| Female | 114 (26.5%) | 1813 (30.8%) | 1927 (30.5%) |
| Male | 317 (73.5%) | 4066 (69.2%) | 4383 (69.5%) |
| Injury severity score (ISS) |  |  |  |
| Mean (SD) | 18.9 (11.3) | 12.0 (13.5) | 12.4 (13.4) |
| Median [Min, Max] | 17.0 [0, 75.0] | 9.00 [0, 75.0] | 9.00 [0, 75.0] |
| Missing | 0 (0%) | 8 (0.1%) | 8 (0.1%) |
| Respiratory rate |  |  |  |
| Mean (SD) | 19.0 (5.29) | 18.4 (4.86) | 18.4 (4.89) |
| Median [Min, Max] | 18.0 [9.00, 40.0] | 18.0 [0, 60.0] | 18.0 [0, 60.0] |
| Missing | 87 (20.2%) | 1163 (19.8%) | 1250 (19.8%) |
| GCS |  |  |  |
| Mean (SD) | 13.8 (2.68) | 14.1 (2.39) | 14.1 (2.41) |
| Median [Min, Max] | 15.0 [3.00, 15.0] | 15.0 [3.00, 15.0] | 15.0 [3.00, 15.0] |
| Missing | 44 (10.2%) | 655 (11.1%) | 699 (11.1%) |
| Systolic Blood Pressure |  |  |  |
| Mean (SD) | 134 (31.2) | 133 (33.9) | 133 (33.7) |
| Median [Min, Max] | 135 [0, 237] | 135 [0, 285] | 135 [0, 285] |
| Missing | 11 (2.6%) | 117 (2.0%) | 128 (2.0%) |
| Resuscitation procedure |  |  |  |
| None | 186 (43.2%) | 4340 (73.8%) | 4526 (71.7%) |
| Radiological intervention | 32 (7.4%) | 50 (0.9%) | 82 (1.3%) |
| Thoracic drainage | 36 (8.4%) | 301 (5.1%) | 337 (5.3%) |
| External fracture fixation | 20 (4.6%) | 123 (2.1%) | 143 (2.3%) |
| Other intervention | 3 (0.7%) | 41 (0.7%) | 44 (0.7%) |
| Thoracotomy | 8 (1.9%) | 88 (1.5%) | 96 (1.5%) |
| Craniotomy | 39 (9.0%) | 196 (3.3%) | 235 (3.7%) |
| Pelvic packing | 0 (0%) | 5 (0.1%) | 5 (0.1%) |
| Surgical wound revision | 25 (5.8%) | 284 (4.8%) | 309 (4.9%) |
| Laparotomy - hemostasis | 25 (5.8%) | 157 (2.7%) | 182 (2.9%) |
| Intracranial pressure measurement as sole intervention | 13 (3.0%) | 63 (1.1%) | 76 (1.2%) |
| Major fracture surgery | 33 (7.7%) | 202 (3.4%) | 235 (3.7%) |
| Revascularization | 11 (2.6%) | 29 (0.5%) | 40 (0.6%) |
| Mortality (within 30 days) |  |  |  |
| Dead | 34 (7.9%) | 565 (9.6%) | 599 (9.5%) |
| Alive | 395 (91.6%) | 5304 (90.2%) | 5699 (90.3%) |
| Missing | 2 (0.5%) | 10 (0.2%) | 12 (0.2%) |

GCS = Glasgow Coma Scale, OFI = Opportunity for improvement

### Associations with Opportunities for improvement

At least one OFI was reported in 431 (6.8%) cases. The median age in the OFI patient group was 47 years, and in the no-OFI patient group was 42 years. In the OFI patient group, 317 (73.5%) were male and 114 (26.5%) were female, and in the no-OFI patient group, the corresponding rates were 4066 (69.2%) and 1813 (30.8%), respectively. The OFI patient group had a higher mean ISS score (18.9) compared to the no-OFI group (12). However, the rates of Glasgow Coma Scale (GCS), systolic blood pressure, and respiratory rate were similar in both groups.

There was a lower proportion of patients who did not undergo any resuscitation procedures in the OFI group compared to the non-OFI group (43.2% vs. 73.8%). Among the resuscitation procedures performed in this group, craniotomy was the most common, followed by thoracic drainage major fracture surgery, and radiological intervention.

Compared to the no-OFI group, the proportion of patients who underwent craniotomy and thoracic drainage was higher, at 9.0% vs. 3.3% and 8.4% vs. 5.1%, respectively. Major fracture surgery and radiological intervention were also more common in OFI compared to the non-OFI patient group, 7.4% vs. 0.9% and 7.7% vs. 3.4% (Table 1).

### The clinical significance of OFI

In multivariable regression analysis, revascularization OR 0.13, CI: 0.06-0.32, p <0.001), radiological intervention (OR 0.16, CI: 0.09-0.28, p <0.001), intracranial pressure measurement as sole intervention (OR 0.19, CI: 0.07-0.52, p <0.001), craniotomy (OR 0.26, CI: 0.15-0.48, p <0.001), and external fracture fixation (OR 0.36, CI: 0.22-0.65, p <0.001) were all significantly associated with a lower odds for OFI compared to patients who did not receive any resuscitation procedures. The OR for OFI in patients treated with laparotomy-hemostasis and major fracture surgery were also significantly 0.5 (CI: 0.29, 0.91, p=0.018) and 0.44 (95% CI: 0.29, 0.71, p <0.001). However, thoracic drainage, thoracotomy, surgical wound revision, pelvic packing, and other interventions are not significantly associated with the odds of OFI.

Additionally, both 30-day mortality (OR 0.31, CI: 0.14-0.61, p=0.001) and ISS (OR 0.94, CI: 0.93, 0.95, p<0.001) had a significant association with OFI. However, neither age, gender, systolic blood pressure, respiratory rate, and GCS were not significantly associated with the odds of OFI.

The logistic regression analysis provides a more accurate understanding of the relationship between resuscitation procedures and the presence of OFI, as it adjusts for potential confounders.

**Table 2. The association of OFI adjusted for potential confounders.**

Logistic regression analysis comparing the presence of OFI in relation to clinical data and intervention procedures during the initial in-hospital assessment.

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristic** | **OR** | **95% CI** | **p-value** |
| **Gender** |  |  |  |
| Female | — | — |  |
| Male | 0.92 | 0.71, 1.20 | 0.6 |
| **Mortality (within 30 days)** |  |  |  |
| Dead | — | — |  |
| Alive | 0.31 | 0.14, 0.61 | 0.001 |
| **Age** | 0.99 | 0.99, 1.00 | 0.027 |
| **Systolic Blood Pressure** | 1.00 | 0.99, 1.00 | 0.2 |
| **Respiratory rate** | 1.00 | 0.98, 1.03 | 0.8 |
| **GCS** | 0.94 | 0.88, 1.00 | 0.059 |
| **Injury severity score (ISS)** | 0.94 | 0.93, 0.95 | <0.001 |
| **Resuscitation procedure** |  |  |  |
| None | — | — |  |
| Radiological intervention | 0.16 | 0.09, 0.28 | <0.001 |
| Thoracic drainage | 0.69 | 0.42, 1.15 | 0.14 |
| External fracture fixation | 0.36 | 0.22, 0.65 | <0.001 |
| Other intervention | 1.10 | 0.32, 6.94 | >0.9 |
| Thoracotomy | 1.91 | 0.32, 37.6 | 0.6 |
| Craniotomy | 0.26 | 0.15, 0.48 | <0.001 |
| Pelvic packing | 228,781 | 0.00, NA | >0.9 |
| Surgical wound revision | 0.64 | 0.38, 1.13 | 0.10 |
| Laparotomy - hemostasis | 0.50 | 0.29, 0.91 | 0.018 |
| Intracranial pressure measurement as sole intervention | 0.19 | 0.07, 0.52 | <0.001 |
| Major fracture surgery | 0.44 | 0.29, 0.71 | <0.001 |
| Revascularization | 0.13 | 0.06, 0.32 | <0.001 |

OR = Odds ratio, CI = Confidence interval, GCS = Glasgow Coma Scale, OFI = Opportunity for improvement

# Discussion

We conducted a registry-based study to investigate the association between immediate interventions in trauma care and OFI. We used data on trauma patients with information on OFIs identified during M&M reviews and found that 7 out of 12 resuscitation procedures had statistical significance. OFIs were found in 6.8% of all cases, and a higher proportion of patients in the OFI group received an intervention than in the no-OFI group, suggesting a potential association between these procedures and OFI. However, the multivariable logistic regression analysis showed that these procedures were associated with lower odds of OFI, meaning that patients who underwent these interventions were less likely of having an OFI compared to those who did not.

There was limited data from studies that have been designed specifically to investigate the impact of these procedures on patient outcomes. We were not able to find any other published studies that have investigated the same variables and outcomes in a similar population or setting, hence it was difficult to compare our findings with previous studies.

The association between resuscitation procedures and OFI varied from 44% to 87%. Patients receiving revascularization were predicted to have 87% decreased odds for OFI compared to patients not receiving an intervention. Followed closely by radiological intervention, intracranial pressure measurement as a sole intervention, and craniotomy, with 84%, 81%, and 74% lower odds, respectively. While major fracture surgery, laparotomy for hemostasis, and external fracture fixation were the interventions with the highest risks of OFI among the interventions, they were still associated with 56%, 50%, and 44% lower odds of having an OFI compared to no intervention. Suggesting that even with these potential risks, the benefits of these interventions in terms of reducing morbidity and mortality may outweigh the risks.

An explanation for the low association with OFI could be the fact that these interventions require specialized expertise and resources (34–40) and may be associated with a higher risk of complications or errors if not performed in a timely or appropriate manner and may only be performed by highly trained specialists. It is worth noting that certain procedures did not show a significant association with OFI. Additional investigation may be required to assess the connection between these procedures and OFI.

Higher ISS is associated with an increased risk of OFIs, as indicated by the higher mean and median ISS among patients with OFIs compared to those without. However, the logistic regression analysis revealed that each one-unit increase in ISS was associated with a 6% decrease in the odds of having OFI. This unexpected result may be due to the greater caution exercised by healthcare providers in managing trauma care for patients with more severe injuries.

Patients who survive beyond 30 days after trauma had a lower risk of OFI compared to those who die within 30 days, indicating that OFI contributes to the overall mortality rate in trauma patients. One possible explanation for this association is that patients who die within 30 days after trauma may have received inadequate or delayed care.

Overall, the results indicate that patients who receive immediate trauma interventions have a lower likelihood of experiencing OFI.

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