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

## 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

# 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 (2). In 2020, the world health organization (WHO) estimated that trauma resulted in about 4.4 million deaths, constituting approximately 8% of all deaths globally (3). Furthermore, treating, and rehabilitating trauma patients requires a multidisciplinary approach, leading to considerable public health care burdens and substantial personal, societal, and economic costs (4). For example, Chen *et al.* (2019) calculated the financial burden of all road traffic-related injuries in 166 countries and estimated that road injuries alone would cost the world economy US$1.8 trillion in 2015–30. These costs are equivalent to 0.12% of an annual tax on global domestic products (5).

According to WHO, the primary causes of trauma include road traffic injuries, interpersonal violence, suicide, drowning, and fall accidents (3). 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 (6).

### 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 (7). LMICs face challenges in trauma care delivery due to inadequate funding, insufficient personnel, and sub-optimal infrastructure (7–9). A widely advocated solution to address the shortage of healthcare professionals is ‘task-sharing,’ where tasks are delegated to less specialized personnel or non-healthcare workers (10).

Furthermore, addressing trauma care-related issues in LMICs is challenging due to incomplete and inconsistent data collection on trauma care. This inadequacy impedes accurate and reliable information aggregation, leading to difficulties in influencing public health policies (8,9).

In contrast, high-income countries (HIC) have well-established trauma systems with specialized centers, trained 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. It is an organized and coordinated network of pre-hospital and in-hospital healthcare facilities and services integrated with the local public health organizations designated to provide optimal care to trauma patients (11). 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 (13).

### Trauma centers

Trauma centers are specialized hospital units that are equipped and staffed with experienced medical professionals to provide multidisciplinary advanced care. The level of care provided by a trauma center varies from the highest (level I) to the lowest (Level IV) level of care. Trauma care verification is an independent benchmarking process to evaluate and improve the care for trauma patients. The trauma care verification is achieved by reviewing a trauma service by an invited multidisciplinary team according to international standards, finding strengths and weaknesses, and providing recommendations for potential improvement. Trauma center verification is associated with better patient outcomes (13,14, 31), particularly for those with severe injuries. A study conducted in Sweden found that trauma centers provide a substantial survival advantage, reducing the risk of mortality by over 70% for individuals with severe trauma (ISS ≥ 50) (15).

### Trauma quality improvement programs

The World Health Organization (WHO), the International Association for Trauma Surgery and Intensive Care, and the International Society of Surgery published joint TQI guidelines in 2009 (16). The guidelines advocate the conduction of 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 (31). These trauma centers are supported by a network of prehospital medical professionals and emergency services, including helicopter-based transport to trauma centers (2).

All emergency hospitals are affiliated with SweTrau, the only nationwide trauma database in the country. It has been operational since 2011 and serves as a resource for systematically aggregating and evaluating trauma care data. In 2021 the national coverage rate for reported trauma cases reached 77% (34).

### Opportunities for improvement (OFI)

The Opportunity for Improvement (OFI) is an indicator commonly used within TQIPs to identify areas for enhancing trauma care delivery (16). OFIs have been found at both system and personnel levels. These include errors in judgment, delayed or inappropriate treatment, and procedural errors (18–20).

The emergency department is the first point of contact for patients with traumatic injuries, and its effectiveness can significantly impact patient outcomes. 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). The emergency department has been identified as a common area where opportunities for improvement in trauma care exist (21,22).

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 (21).

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 (23). 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 (24).

### 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 aims of primary care early in trauma assessment are stabilizing the patient and preserving vital organ functions (12). It is known that the leading cause of OFIs is human errors during emergency initial care. (22–24,27–29).

To improve trauma care and patient outcomes, it is important to find areas with potential for improvement. 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 immediate trauma care procedures are associated with OFIs in trauma care.

# Methods

### Study design

We conducted a registry-based study using data on trauma patients in two registries at Karolinska University Hospital (KUH): the trauma registry and the trauma care quality database. The trauma registry reports to the Swedish Trauma Registry, including demographics, pre-hospital, hospital, and post-hospital care information, following the Utstein template (30). The trauma care quality database consists of cases selected for the M&M conference with details 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 a primary trauma center for the Stockholm region and surrounding 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 (31). All high-priority trauma patients in Stockholm are transported to KUH for initial trauma assessment and treatment.

In case of the suspected presence of OFI, a multidisciplinary team discusses the patient in the M&M conference. In addition, the presence of OFI during trauma assessment is evaluated by a specialized trauma nurse on digital-based audit filter protocols.

Regardless of the presence of OFI, all patients are recorded in the trauma care quality database.

### 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 ISS is based on the Abbreviated Injury Scale, which assigns a score from 1 to 6 to injuries in various body regions based on their severity. The AIS scores are then squared and summed for the three most severely injured body regions, resulting in a total ISS score ranging from 1 to 75 (35).

The trauma care quality database includes all patients reviewed by the M&M board. In addition, these patients are selected for review at M&M conferences by two specialized nurses. After collecting data on patients registered between 2017 and 2021, we conducted a complete case analysis, which involved excluding any patients with missing data in either the outcome variable, the covariates, or the independent variables (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.

### 

### Variables

***Study outcome***

The study’s primary endpoint is OFI, a binary variable of “Yes” or “No”. The outcome will be either “Yes” if at least one OFI is found or “No” if no OFIs are identified. We obtain data about OFIs from the trauma care quality database.

***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). Multivariable logistic regression was conducted to predict the relationships between OFIs (dependent variable) and emergency procedures (independent 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, of which x were excluded due to incomplete data. Patient characteristics for the remaining patients are summarized in Table 1. The study population consists of 4383 (68%) males and 1927 (31%) females, with a median age of 45. 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 was 14.1. The median 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).

|  |  |  |  |
| --- | --- | --- | --- |
|  | 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%) |

### Opportunities for improvement in relation to clinical data

At least one OFI was reported in 431 (6.8%) cases. The median age in the OFI patient group was 48 years, and in the non-OFI patient group was 42 years. Among the OFI patient group, 317 (73.5%) were males, 114 (26.5%) were females, and in the non-OFI patient group, the corresponding rates were 4066 (69.2%) and 1813 (30.8%), respectively. The mean ISS score was higher in the OFI group compared to the no-OFI group (18.9 vs. 12). The mean respiratory rate was higher in the OFI group (19) than in the non-OFI group (18.4). The mean GCS score was lower in the OFI group (13.8) than in the non-OFI group (14.1). The mean systolic blood pressure was similar in both groups, with values of 134 mmHg in the OFI group and 133 mmHg in the non-OFI group. The most common resuscitation procedures in the OFI patient group were the radiological intervention, thoracic drainage, and major fracture surgery, and were performed in 33 (7.7%), 36 (8.4%), and 32 (7.4%) patients, respectively. The corresponding rates for these procedures in the non-OFI group were 50 (0.9%), 301 (5.1%), and 202 (3.4%) patients, respectively (Table 1).

### The clinical significance of OFI

In multivariable regression analysis, the presence of OFI was inversely correlated to age and ISS with OR rates of 0.99 (CI 0.99-1, p-value 0.027) and 0.94 (CI 0.93-0.9, p-value <0.001), respectively. OFI had a negative association with 30 days mortality OR 0.31 (CI 0.14-0.61, p=0.001). Gender, systolic blood pressure, respiratory rate, or GCS were not found to be significant predictors of OFI.

Among the resuscitation procedure, revascularization, radiological intervention, craniotomy, external fracture fixation, intracranial pressure measurement as sole intervention, laparotomy-hemostasis, and major fracture surgery had significant associations with OFI.

Revascularization had the strongest negative association with OFI OR 0.13 (95% CI: 0.06-0.32), followed by radiological intervention OR 0.16 (95% CI: 0.09-0.28), intracranial pressure measurement as sole intervention OFI OR 0.19 (95% CI: 0.07-0.52), craniotomy OR 0.26 (95% CI: 0.15-0.48), and external fracture fixation OR 0.36 (95% CI: 0.22-0.65) all with a p-value <0.001. Laparotomy-hemostasis OR (95% CI: 0.29, 0.91, p-value 0.018) and major fracture surgery also have significant negative associations with OFI but to a lesser degree OR 0.44 (95% CI: 0.29, 0.71, p-value <0.001).

Interventions that were not significant predictors of OFI were thoracic drainage, thoracotomy, pelvic packing, surgical wound revision, intracranial pressure measurement, and pelvic packing.

|  |  |  |  |
| --- | --- | --- | --- |
| **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 |

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