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

# Introduction

**Background**

is a condition resulting from physical injury and the body’s associated response (1). Depending on injury mechanisms, trauma can be classified into three major types: penetrating, blunt, and deceleration trauma. Major trauma 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). Primary causes of trauma include road traffic injuries, interpersonal violence, suicide, drowning, and fall accidents (2).

The disability-adjusted life year (DALY) is an index that is used to estimate the burden of disease and total health loss at the population level by aggregating the mortality in years of life lost (YLLs) and the non-fatal health outcomes in years lived with disability (YLDs), and constitutes a comprehensive measure of the magnitude of different health problems, such as the consequences of trauma (2). Road injuries are the leading contributor to adult DALYs (26%) followed by interpersonal violence (14%) for young adults, while fall accidents rank in the top ten causes of DALYs for individuals aged seventy-five and above (4). The treatment and rehabilitation of trauma patients require a multidisciplinary approach with extensive healthcare resources, resulting in considerable public healthcare 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).

### Trauma Care and trauma care quality improvement

Survival rates after a traumatic event are influenced by multiple factors. Injury severity, quality and speed of care, and access to specialized trauma care facilities are the most crucial factors affecting a patient's chance of survival. Multiple Trauma Quality Improvement (TQI) initiatives originating in high-income countries have emerged to enhance trauma care worldwide. These initiatives include the adoption of ATLS protocols, the Eastern Association for the Surgery of Trauma’s clinical practice guidelines, and the establishment of local and national trauma databases. Moreover, the global changes brought about by trauma system regionalization have been particularly impactful, leading to a more streamlined and coordinated approach to trauma care delivery (20).

Trauma systems manage the entire trauma care pathway, from the point of injury, pre-hospital care, emergency department resuscitation, specialist emergency surgical intervention, and rehabilitation until the patient is reintegrated into society (9, 10). The survival rates of patients within trauma a system is significantly influenced by the stage of development of the system. In established trauma systems, trauma centers play a crucial role. By providing multidisciplinary advanced care, the presence of trauma centers is associated with improved patient outcomes, particularly for those with severe injuries. Trauma centers are nowadays an essential part of larger hospitals and serve as the designated facility for the regional trauma system (10, 12). In the United States, trauma centers are classified into four levels by the American College of Surgeons Committee on Trauma, based on trauma patient volume, staff requirements, and educational and research activities where level 1 provides the most advanced care ().

In line with the centralization of trauma to regional health care providers trauma center verification has emerge as an independent benchmarking process that assesses and improves the care provided to trauma patients (9). Currently, the verification is an essential part of the trauma system and is often included in trauma quality improvement programs(TQIP). Similar to other TQI initiatives, the implementation of TQIPs correlates with how developed trauma systems are. The need to incorporate, and hence the trend to include TQIPs in trauma care, is increasing during the development of a trauma system.

In 2009, WHO, the International Association for Trauma Surgery and Intensive Care, and the International Society of Surgery published joint guidelines for TQIPs to establish a global standard of care for trauma patients and a framework for trauma system development (15). Important TQIPs highlighted in the guidelines were morbidity and mortality M&M conferences, preventable death panel reviews, trauma registries and audit filters.

The M&M conferences are effective forums for learning and reflection, providing opportunities for healthcare personnel, faculties and trainees to discuss management details of particular patient cases when morbidity or mortality occurs. The aim of M&M meetings is to identify and explore errors contributing to adverse outcomes in order to gain insight into clinical routines and improve clinical assessment without personal blame. In the trauma care system, multidisciplinary trauma teams discuss all adverse events and errors in patient care and the hospital system during regular M&M conferences. These meetings aim to identify opportunities for improvement (OFI) in the entire patient care process. During these meetings, corrective action plans are developed and evaluated. Similarly, preventable death panels is another quality improvement, and patient safety initiative which involve multidisciplinary teams that aim to identify OFIs. While M&M conferences cover a broader range of cases and issues, preventable death panels concentrate on determining whether the deaths were preventable. They serve as an extension to the M&M conferences with the goal to pinpoint changes in the medical care process that could have resulted in better patient outcomes. It is recommended that resources such as hospital records, prehospital information, traffic safety and police records, autopsy reports, death certificates, input from care providers involved in the case, and trauma registry data, if obtainable are used in the quality improvement meetings.

Trauma registries are essential for identifying opportunities for improvement (OFIs) in trauma care. They provide comprehensive information on patterns and trends of injuries, complications, and outcomes, aiding in tracking, monitoring, and improving the quality of trauma care. However, data collection is a time and resource process. To address this, many initiatives have adopted the use of audit filters to automate and streamline the process. These filters have predefined criteria that determine normal ranges for the variables of interest. Any data points outside of these ranges are defined as exceptions and collected for further analysis. TQI initiatives are aided by the establishment and maintenance of trauma databases at local and national levels to track outcomes. These databases have enabled the evaluation of the effectiveness of TQI efforts (20). However, to obtain comparable data globally and identify find areas for potential improvement in trauma care, there is a need for an international trauma registry.

### 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. The input variables in SweTrau were selected through a European consensus effort in 2009 to standardize data collection for cross-country trauma care analysis by experts from Scandinavia, the United Kingdom, Germany, and Italy (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).

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### Opportunities for improvement (OFI)

Due to the urgent need for prompt diagnosis and treatment in a stressful environment, medical errors and mismanagement are prevalent in trauma care, putting many patients at risk of serious complications or death. In fact, multiorgan dysfunction, hemorrhage, and airway management failure are the most common causes of death (23-25). To identify areas that need improved trauma care delivery TQIPs commonly use OFI as an indicator (15). OFIs are typically classified as either system-level or personnel-level OFIs, although there can be some overlap between the two categories. Typical system-level OFIs include interhospital transfers, trauma team activation issues, pre-hospital delays, delays in imaging, and sub-optimal organization of resources (20, 24, 25). A consequence of these OFIs is that they can cause treatment delays, which can reslut in a significant number of preventable deaths.

The nature and prevalence of OFIs may vary depending on the specific healthcare setting, available resources, and the most common mechanism of injury treated at the setting. However, evidence show that the most frequent cause of preventable trauma deaths is human error (19-23). Clinical judgment errors are the type of human error that has the most significant impact on trauma care. Missed injuries, inappropriate treatment, inadequate monitoring, and procedural errors, are frequently observed judgment errors in trauma care (19, 20, 23). The errors occur at all stages of care, but they are more prevalent during the initial resuscitation (19-25).

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).

Addressing OFIs is crucial for improving trauma care and patient outcomes, particularly during the early phase of trauma care. Previous studies have shown that OFIs are common during this phase, but the specific reasons for them remain largely unknown. Understanding the underlying causes of OFI during this phase might be essential to improve patient outcomes. Examining the association between OFIs and early resuscitation procedures could help achieve this goal. However, to our knowledge, no prior studies have been conducted on this subject.

Furthermore, previous research on OFIs has primarily focused on patients who have died, excluding patients who have experienced disability after trauma. This has resulted in a significant gap in knowledge about trauma care since trauma is a significant contributor to morbidity and disability worldwide. More profound knowledge of the association between OFIs and early resuscitation procedures in patients with adverse events might guide TQI efforts and subsequently will result in reduced mortality and morbidity.

# Aim

The aim of this study was to assess how emergency procedures are associated with OFIs in trauma care in patients with both mortality and morbidity as outcome.

# 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 quality database reports to the national trauma registry, including demographics, pre-hospital, hospital, and post-hospital care, 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 located 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.

The patients treated at KUH were recorded in the Swedish national trauma registry. Inclusion of patient cases in the M&M conference was linked to the recording of patient cases in the national trauma registry. A specialized nurse assessed each patient case during registration in the national trauma registry, flagging cases suspected of having OFI. To assist with the selection process, all cases were passed through an automated audit filter that identified cases based on specific criteria listed below. Subsequently, the nurse, along with another specialized nurse, conducted a secondary, more thorough review of the cases, looking through patient charts, ambulance reports, and test results based on the criteria triggered by the audit filter to determine if inclusion in the M&M conference was appropriate. If anything was unclear in the initial manual review, it was addressed during this secondary review.

During the conference, the cases were classified according to the presence of OFI determined through consensus by the attending board, and subsequently, registered in the quality database. Board members in included nurses and doctors from all specialties involved in the patient care (Figure 1).

**Audit filters**

|  |  |  |  |
| --- | --- | --- | --- |
| Systolic blood pressure less than 90  Glasgow coma scale less than 9 and not intubated  Injury severity score greater than 15 but not admitted to the intensive care unit  Time to acute intervention more than 60 minutes from arrival to hospital  Time to computed tomography more than 30 minutes from arrival to hospital  No anticoagulant therapy within 72 hours after traumatic brain injury  The presence of cardio-pulmonary resuscitation with thoracotomy  The presence of a liver or spleen injury  Massive transfusion, defined as 10 or more units of packed red blood cells within 24 hours. |  |  |  |

### 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 (Figure 1).

The national 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.

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**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 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 had 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

The study included 11864 patients of which 5554 patients were excluded due to missing data and age under 15. Characteristics for the remaining 6310 patients are summarized in Table 1.

Missing data.

The study included 6,310 trauma patients, with 69.5% male and 30.5% female, median age 43.0 [15.0, 100]. Mean ISS was 12.4 (median 9), respiratory rate was 18.4, GCS was 14.1, and systolic blood pressure was 133 mmHg. Most common interventions were craniotomy (n=235), surgical wound revision (n=309), and major fracture surgery (n=235). 30-day mortality rate after trauma was 9.5% (n=599).

**Table 1. Patient characteristics divided by the presence of opportunities for improvement**

|  |  |  |  |
| --- | --- | --- | --- |
|  | 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 OFI group had a median age of 47 years, with 317 (73.5%) male and 114 (26.5%) female. While the no-OFI group had a median age of 42 years, with 4066 (69.2%) male and 1813 (30.8%) female. OFI patients had a higher mean ISS score (18.9) compared to the no-OFI group (12). However, both groups had similar rates of Glasgow Coma Scale (GCS), systolic blood pressure, and respiratory rate.

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

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

In multivariable regression analysis, revascularization OR 7.44, CI: 3.14-16.3, p <0.001), radiological intervention (OR 6.33, CI: 3.62-10.9-0.28, p <0.001), intracranial pressure measurement as sole intervention (OR 5.29, CI: 1.91-13.7, p <0.001), craniotomy (OR 3.82, CI: 2.09-6.82, p <0.001), and external fracture fixation (OR 2.74, CI: 1.53-4.64, p <0.001) were all significantly associated with a higher odds of OFI compared to patients who did not undergo any emergency procedures. The OR of OFI in patients treated with laparotomy-hemostasis (OR 2.00, CI: 1.10-3.48, p 0.018) and major fracture surgery (OR 2.26, CI: 1.42, 3.48, p<0.001) were also significant. and 0.44 (95% CI: 0.29, 0.71, p <0.001). However, thoracic drainage, thoracotomy, surgical wound revision, pelvic packing, and other interventions were not significantly associated with the odds of OFI.

Additionally, both being alive at 30 days (OR 3.25, CI: 1.64-7.02, p=0.001) and ISS (OR 1.07, CI: 1.05, 1.08, p<0.001) were significantly associated with OFI. However, neither age, gender, systolic blood pressure, respiratory rate, and GCS were significantly associated with the odds of OFI.

**Table 2. Associations of the variables and OFI**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristic** | **OR** | **95% CI** | **p-value** |
| **Gender** |  |  |  |
| Female | — | — |  |
| Male | 1.08 | 0.83, 1.42 | 0.6 |
| **Mortality (within 30 days)** |  |  |  |
| Dead | — | — |  |
| Alive | 3.25 | 1.64, 7.02 | 0.001 |
| **Age** | 1.01 | 1.00, 1.01 | 0.027 |
| **Systolic Blood Pressure** | 1.00 | 1.00, 1.01 | 0.2 |
| **Respiratory rate** | 1.00 | 0.97, 1.02 | 0.8 |
| **GCS** | 1.06 | 1.00, 1.14 | 0.059 |
| **Injury severity score (ISS)** | 1.07 | 1.05, 1.08 | <0.001 |
| **Emergency procedure** |  |  |  |
| None | — | — |  |
| Radiological intervention | 6.33 | 3.62, 10.9 | <0.001 |
| Thoracic drainage | 1.46 | 0.87, 2.35 | 0.14 |
| External fracture fixation | 2.74 | 1.53, 4.64 | <0.001 |
| Other intervention | 0.91 | 0.14, 3.16 | >0.9 |
| Thoracotomy | 0.52 | 0.03, 3.08 | 0.6 |
| Craniotomy | 3.82 | 2.09, 6.82 | <0.001 |
| Pelvic packing | 0.00 |  | >0.9 |
| Surgical wound revision | 1.57 | 0.89, 2.60 | 0.10 |
| Laparotomy - hemostasis | 2.00 | 1.10, 3.48 | 0.018 |
| Intracranial pressure measurement as sole intervention | 5.29 | 1.91, 13.7 | <0.001 |
| Major fracture surgery | 2.26 | 1.42, 3.48 | <0.001 |
| Revascularization | 7.44 | 3.14, 16.3 | <0.001 |

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