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

***A registry-based retrospective cohort study***

Final version

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**Associationer mellan akuta åtgärder och möjligheter till förbättringar hos vuxna trauma patienter: En retrospektiv kohortstudie baserad på registerdata**

*Bakgrund:* Trauma orsakade cirka 4,4 miljoner dödsfall under 2020, ca 8% av alla dödsfall globalt. Ett initiativ till att förbättra och utvärdera traumavård är utvecklingen av traumaregister. Datan i dessa används för att identifiera möjligheter till förbättringar (OFI) i vårdprocessen. Den tidiga fasen av traumavård har störst potential för förbättring. Man har även sett att mycket fel sker på individnivå vid utförandet av livräddande interventioner. *Syfte*: Denna studie syftade till att bedöma huruvida akuta interventioner är associerade med förbättringspotential i traumavård av vuxna patienter. *Metod:* En retrospektiv kohortstudie genomfördes med data från Svenska Traumaregistret och kvalitetsdatabasen för traumavård vid Karolinska Universitetssjukhuset i Solna. Sambanden mellan 12 interventioner och förbättringspotential (OFI) bedömdes med hjälp av multivariabel logistisk regression. *Resultat*: Studien inkluderade 6 310 trauma patienter, varav 431 (6,8%) hade OFI. Hos patienter som man funnit OFI hade en medianålder på 47 år, medan de som inte hade OFI hade en medianålder på 42 år. Flera interventioner var signifikant associerade med OFI, inklusive revaskularisering (OR 7.44, CI: 3.14, 16.3, p <0.001), radiologisk intervention (OR 6.33, CI: 3.62, 10.9, p <0.001), intrakraniell tryckmätning som enda åtgärd (OR 5.29, CI: 1.91, 13.7, p <0.001), kraniotomi (OR 3.82, CI: 2.09, 6.82, p <0.001), extern frakturfixation (OR 2.74, CI: 1.53, 4.64, p <0.001), laparotomi för hemostas (OR 2.00, CI: 1.10, 3.48, p 0.018) och större frakturkirurgi (OR 2.26, CI: 1.42, 3.48, p <0.001). Överlevnad efter 30 dagar, ålder och Injury Severity Score utgjorde prognostiska faktorer för att prediktera OFI. *Slutsats*: Radiologisk intervention, extern frakturfixation, kraniotomi, laparotomi för hemostas, intrakraniell tryckmätning som enda åtgärd, större frakturkirurgi och revaskularisering var signifikant associerade med förbättringspotential. Vidare undersökning av orsakerna bakom associationerna mellan dessa interventioner och förbättringspotential är viktigt för utvecklingen av traumavård.

**Associations between emergency procedures and opportunities for improvement in adult trauma patients: *A registry-based retrospective cohort study***

*Introduction:* Trauma caused approximately 4.4 million deaths in 2020, accounting for about 8% of all deaths globally. An initiative to improve trauma care was the development of trauma registries. They provide data that can be used to identify opportunities for improvements (OFI) in trauma care. The early phase of care has the highest potential for improvement. It has been found that most errors occur when emergency procedures are provided. *Aims:* This study aimed to assess if and how emergency procedures are associated with OFIs in the trauma care of adult patients. *Methods:* A retrospective cohort study was conducted using data from the Swedish Trauma Registry and the trauma care quality database at the Karolinska University Hospital in Solna. The associations between 12 procedures and OFI were evaluated using multivariable logistic regression. *Results:* The study included 6,310 trauma patients, of which 431 (6.8%) experienced OFI. Patients with OFI had a median age of 47 years, while those without had a median age of 42. Several interventions were significantly associated with OFI, including revascularisation (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), external fracture fixation (OR 2.74, CI: 1.53-4.64, p <0.001), 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). Survival after 30 days, age, and Injury Severity Score had a prognostic impact in predicting the presence of OFI. *Conclusions:* Radiological intervention, external fracture fixation, craniotomy, laparotomy for hemostasis, intracranial pressure measurement as the sole intervention, major fracture surgery, and revascularisation were significantly associated with an increased risk of OFI. Further investigation is needed to explore the causes of the OFI in these interventions.

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*Keywords:* Trauma, quality care, preventable errors, opportunities for improvement, audit filters

# List of Abbreviations

DALY – Disability-Adjusted Life Years

GCS — Glasgow Coma Scale

ISS — Injury Severity Score

KUH - Karolinska University Hospital

M&M - Morbidity and Mortality

OFI — Opportunity for Improvement

SweTrau — Swedish National Trauma Registry

TQIP – Trauma quality improvement program

WHO - World Health Organization

# Introduction

**Trauma**

Trauma is a condition that occurs due to violence or accident resulting in physical injuries, such as wounds, bone fractures and internal organ damage, that require an immediate medical assessment. Primary causes of trauma include road traffic injuries, interpersonal violence, suicide, drowning, and fall accidents (1–3). Depending on injury mechanisms, trauma can be classified into two major types: penetrating and blunt trauma. Major trauma is a significant cause of death and permanent disability worldwide (4). In 2020, the world health organization (WHO) estimated that trauma resulted in about 4.4 million deaths, constituting approximately 8% of all deaths globally (1).

The consequences of trauma, such as the impacts on health, can be assessed using the disability-adjusted life year (DALY) index. This index combines the mortality in years of life lost (YLLs) and the non-fatal health outcomes in years lived with disability (YLDs), providing a comprehensive measure of the overall burden of disease and health loss at a population level (1). Road injuries are the leading contributor to adult DALYs (26%), followed by interpersonal violence (14%) for young adults. Fall accidents rank in the top ten causes of DALYs for individuals aged seventy-five and above (5). In addition to lost health, the treatment and rehabilitation of trauma patients require extensive healthcare resources, resulting in considerable public healthcare burdens (6). 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 (7).

**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 (10). Multiple Trauma Quality Improvement (TQI) initiatives originating in high-income countries have emerged to enhance trauma care worldwide (4). These initiatives include the adoption of Advanced Trauma Life Support protocols, the Eastern Association for the Surgery of Trauma’s clinical practice guidelines and the establishment of local and national trauma databases.

The implementation of trauma systems has been particularly impactful, leading to a more streamlined and coordinated approach to trauma care delivery (9). Trauma systems are coordinated networks of healthcare services within a region that manage the entire care pathway for trauma patients, from injury to rehabilitation. They include patient care from the point of injury, pre-hospital care, emergency department resuscitation, specialist emergency surgical intervention, and rehabilitation until the patient is reintegrated into society (8). Trauma systems are associated with better patient outcomes (9).

The survival rates of patients within a trauma system are significantly influenced by the stage of development of the system (11). 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 (9, 10). Trauma centers are nowadays an essential part of larger hospitals and serve as the designated facility for the regional trauma system (7, 11). 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 (14).

### Trauma quality improvement programs

In response to the centralization of trauma care, trauma center verification has emerged as a necessary means for evaluating and improving the quality of care provided to trauma patients (9). Trauma center verification is an independent evaluation process that aims to standardize the care of trauma patients. This benchmarking process is performed by an independent multidisciplinary team invited to review trauma centers according to international standards. The team will identify strengths and weaknesses in trauma service and suggest recommendations for potential improvements in trauma patient care (15). Trauma center verification by the American College of Surgeons requires the inclusion of the trauma performance improvement program (TQIP) (14). Similar to other TQI initiatives, implementing 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, the 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 (16). Important TQIPs highlighted in these guidelines were morbidity and mortality (M&M) conferences, preventable death panel reviews, trauma registries and audit filters.

The M&M conferences are 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 goal of M&M meetings is to identify and explore errors contributing to adverse outcomes, to gain insight into clinical routines and improve clinical assessment without personal blame (17). 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 (OFIs) in the entire patient care process and implement and evaluate corrective action plans (16). Similarly, preventable death panels are another quality improvement measure and patient safety initiative which involves 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 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 these quality improvement meetings (16).

Trauma registries constitute an essential modality in identifying OFIs. They provide comprehensive information on patterns and trends of injuries, complications, and outcomes, aiding in tracking, monitoring, and improving the quality of trauma care (16). However, handling trauma data is often time and resource-demanding. To address this, many initiatives have adopted the use of audit filters to automate and streamline parts of the data handling process. The audit filter has predefined criteria that determine normal ranges for the variables of interest collected during the course of trauma care. Any data points that fall outside these ranges are marked as exceptions and selected for further analysis. Nonetheless, it is important to note that there is currently limited evidence of their effectiveness (18).

Both local and national trauma registries have been essential in evaluating TQI initiatives (19). However, to obtain standardized data and identify global trends, an international trauma registry is suggested to be necessary (6).

### Opportunities For Improvement

The OFIs are defined as any errors contributing to adverse outcomes identified during M&M conferences. Due to the urgent need for rapid 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. Multiple organ failure, hypovolemic shock, and respiratory failure are common causes of death that are preventable (20–22). To identify areas that need improved trauma care delivery TQIPs commonly use OFI as an indicator. OFIs are broadly classified as either system-level or personnel-level, although there can be some overlap between the categories (19). Typical system-level OFIs include interhospital transfers, trauma team activation issues, pre-hospital delays, delays in imaging, and sub-optimal organization of resources (16, 20, 22). A consequence of these OFIs is that they cause treatment delays, which can result in a significant number of preventable deaths (19).

The type and prevalence of OFIs vary depending on the specific healthcare setting, available resources, and the most common mechanism of injury treated at the setting. However, evidence shows that human error is the most frequent cause of preventable trauma deaths (19, 21). The errors occur at any stage of trauma care but are more common during the initial resuscitation phase (19–23). The classification of human errors can be divided into two categories: clinical judgment errors and procedural errors. Clinical judgment errors result in various adverse outcomes, such as missed injuries, inappropriate treatment, and inadequate monitoring (20). On the other hand, procedural errors are typically the result of the failure to execute established protocols or procedures correctly (19, 20, 23). Several studies have shown that common procedural errors often relate to the management of airway and chest injuries, as well as hemorrhage control (18, 22)

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 human resources and multidisciplinary medical resources. (25,26).

Addressing OFIs is crucial for improving trauma care, particularly during the early phase of trauma care. Previous studies have shown that OFIs are common during the early course of trauma care, but the specific reasons for them remain largely unknown. Understanding the underlying causes of OFIs and exploring their association with emergency procedures is essential to improve patient outcomes. To our knowledge, there is a limited number of studies where this topic is investigated. Moreover, previous research on OFIs has primarily focused on patients who died, excluding patients who survived with potential disabilities, resulting in a significant gap in knowledge about trauma care.

# Aim

This study aimed to assess how emergency procedures are associated with OFIs in trauma care of adult patients.

# Methods

**Study design**

We conducted a registry-based study using two patient registries at Karolinska University Hospital (KUH): the trauma care quality database and the trauma registry. We analysed the data using a multivariable logistic regression model to assess how emergency procedures are associated with OFI.

**Setting**

The Karolinska University Hospital (KUH) in Solna, Stockholm, Sweden, 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-I trauma center defined by the American College of Surgeons (25, 26). Hence, all high-priority trauma patients are transported to KUH for initial trauma assessment and treatment.

The trauma registry at KUH submits patients admitted with trauma team activation, irrespective of their injury severity score, to the Swedish Trauma Registry (SweTrau). It also incorporates patients initially admitted without trauma team activation but subsequently identified with an injury severity score above 9. However, the trauma registry at KUH encompasses a broader range of data than the Swedish Trauma Registry. It includes information on vital signs, time, injuries, interventions, and patient demographics, aligning with the European consensus statement, the Utstein template.

The trauma care quality database at KUH includes information relevant to the mortality and morbidity conferences. This includes audit filters, identification of OFIs, and suggested corrective actions.

Including patient cases for the M&M conference is linked to recording patient cases in the trauma registry at KUH. A specialised nurse assessed each patient case during registration and flagged cases suspected of having OFI. To assist with this process, all cases were passed through an automated audit filter that identified and flagged cases based on the criteria listed in Table 1. Subsequently, the flagged subjects underwent a secondary, more thorough review by two nurses, examining patient charts, ambulance reports, and test results based on the specific criteria triggered by the audit filter to determine if inclusion in the M&M conference was appropriate (Figure 1).

The M&M conferences at KUH involve all professions in trauma care, surgery, neurosurgery, orthopedics, anesthesia, intensive care, nursing, and radiology. During the M&M conference, the cases were classified according to the presence of OFI determined through consensus by the attending board. Corrective actions were determined, and subsequently, the patients were registered in the quality database. Mortality cases were directly included for M&M review, where it was determined whether they were preventable or potentially preventable, categorising them as OFIs.

|  |
| --- |
| **Table 1. Audit filter criteria** |
| 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**

For inclusion, patients had to be recorded in the national trauma registry and the trauma care quality database. 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 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 an available case analysis for all patients discussed (n=6310) at the M&M conferences at KUH, 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.

# Variables

**Study outcome**

The outcome variable is the presence of OFI, as identified during the M&M review, and defined as a binary variable with the levels “Yes - At least one OFI identified” and “No - No opportunities for improvement identified”.

Preventable or possible preventable deaths were also considered as OFI. The data for the outcome was obtained from the trauma care quality database.

**Exposures and covariates**

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.

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

**Bias**

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

**Statistical analysis**

The data was compiled and analyzed using the statistical computing language R (27). The variables were converted and handled according to the SweTrau manual (28). Descriptive statistics, such as mean, median and standard deviation (SD), 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). We adjusted for all variables simultaneously to control for potential confounding factors and evaluate the independent effect of each variable on OFI. The results were presented with a 95% confidence level, and a p-value less than 0.05 was considered significant.

Patients with missing data in either the outcome variable, the covariates, or the independent variables were not included in subsequent statistical analyses comparing OFI with clinical data.

**Ethical considerations**

*Respect for autonomy*

The information used in this study was collected from the SweTrau database (29). 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 could 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 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*

In this retrospective study, we used an existing patient database without involving or altering any treatment or intervention. Hence, the patients are not exposed to any harm. Furthermore, 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 KUH trauma registry included 11864 patients, of which 5554 were excluded because they were not screened for OFI or were younger than 15 years. Characteristics for the remaining 6310 patients are summarized in Table 2. Respiratory rate and GCS had the most cases with missing (19.8% and 11.1%)

The study included 6,310 trauma patients, of which 69.5% were male and 30.5% were female. The mean age was 45 (SD 21.2) years, and the majority of the patients were male (n=4383, 69.5%). The mean ISS was 12.4 (SD 13.4) points, respiratory rate was 18.4 (SD 4.89) breaths per minute, GCS was 14.1 (SD 2.41) points, and systolic blood pressure was 133 (SD 33.7) mmHg.

Thoracic drainage was the most common intervention (5.3%), followed by surgical wound revision (4.9%). Craniotomy and major fracture surgery were the third most common interventions (3.7%). The 30-day mortality rate after trauma for all patients was 9.5% (n=599). However, the survival rate after 30 days after trauma was 9.5% (n=599). Out of the 431 patients who experienced OFI, 395 patients (91.6%) survived their trauma for more than 30 days.

**Table 2. Patient characteristics divided by the presence of opportunity for improvement**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristic** | 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** |  |  |  |
| 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%) |
| ICP | 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, ICP = Intracranial pressure measurement as sole intervention.

**Associations with Opportunit**y **for Improvement**

At least one OFI was reported in 431 (6.8%) cases. Patients with reported OFIs exhibited higher mean age compared to no-OFI patients (48 vs 45). Both groups showed an overrepresentation of males, 73.5% and 69.2%, respectively. OFI patients had a higher mean ISS compared to the no-OFI group, 18.9 (SD 11.3) vs 12 (SD 13.5). However, both groups had similar rates of GCS, systolic blood pressure, and respiratory rate.

In the OFI group, a lower proportion of patients underwent no resuscitation procedures than the no-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, 9.0% vs 3.3% and 8.4% vs 5.1%, respectively.Major fracture surgery and radiological intervention were also more common in the OFI group, 7.4% vs 0.9% and 7.7% vs 3.4% (Table 2).

In the logistic 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, 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 risk of getting OFIs compared to patients who did not undergo any of these emergency procedures. The OR of getting 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 statistically significant, while thoracic drainage, thoracotomy, surgical wound revision, pelvic packing, and other interventions were not associated with OFIs.

Additionally, the presence of OFI was significantly higher in both patients being alive at 30 days after trauma (OR 3.25, CI: 1.64, 7.02, p=0.001) and higher ISS rates (OR 1.07, CI: 1.05, 1.08, p<0.001). Neither age, gender, systolic blood pressure, respiratory rate, or GCS were associated with the presence of OFIs Table 3.

**Table 3. Adjusted Associations between Emergency Procedures 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** | 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 |
| ICP | 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, ICP = Intracranial pressure measurement as sole intervention.

# Discussion

In this registry-based study, we explored the presence of OFI in relation to emergency procedures in trauma care at KUH. OFIs were identified in 6.8% of all patients and were more common in patients who received emergency procedures. Craniotomy and thoracic drainage were the most frequent resuscitation procedures in the OFI and no-OFI patient groups. The OFI group also exhibited a high incidence of radiological interventions, which was not observed in the group without OFI. In patients that received emergency interventions, OFI is found in 10% more patients compared to those who did not receive interventions. The presence of OFI was statistically significant in relation to 7 out of 12 emergency procedures, and the strongest association was found in relation to revascularization (OR 7.44), radiological intervention (OR 6.33), and ICP measurement as sole intervention (OR 5.29).

The knowledge about the occurrence of OFI in trauma care, especially during the initial phase of the care process, is limited. To the best of our knowledge, there are currently no published studies that have explored this specific topic using the same approach and methodology as ours; therefore, it is challenging to compare our findings to results from previously published studies.

Among all the analysed interventions, the highest OR of identifying OFIs was found in patients who received revascularization. These procedures are commonly performed in patients with serious vascular injuries in need of immediate vascular surgery and are frequently associated with complications such as bleeding, thrombosis, and infection (30–34). This complex and time-critical procedure requires rapid decision-making to restore blood flow to ischemic tissues. Consequently, we assume that errors during the immediate and late assessment of these patients are common and hence associated with often reported OFIs.

In severe abdominal trauma with hemorrhage, laparotomy is necessary to achieve hemostasis and repair any injured organs. The OR of reported OFIs in relation to laparotomy for hemostasis was two. Comprehensive data indicate that emergency laparotomy is associated with an increased risk of mortality and morbidity, as well as OFIs. Our data are consistent with previous observations. In a study of 199 patients, Smith et al. reported overall damage control laparotomy mortality rates of 11% and a failure to rescue rate of 8%. Emergency laparotomies are significantly associated with serious postoperative complications such as renal, respiratory, and thromboembolic events. Increased age and preexisting comorbidities are additional risk factors increasing the risk of failure to rescue (35). Moreover, failure to rescue was more common in patients undergoing trauma laparotomies in patients with a higher average of ISS (36). Estimating factors associated with failure to rescue is suggested to improve the quality of interventions in damage control laparotomy and hence clinical patient outcomes (37).

When the source of bleeding is identified, endovascular embolization is performed as a primary emergency intervention. This is a radiologic intervention where the surgeon makes a small incision in the groin area to access a blood vessel, e.g. femoral artery, threads a catheter into a damaged vessel and injects medications or synthetic substances to block blood flow selectively from the bleeding vessel.

In our study, the radiological intervention was significantly associated with OFI. These findings are interesting since laparotomy hemostasis, a more invasive approach for hemostasis, exhibited lower odds of OFI in our analysis. An argument that supports the high prevalence of OFI in radiological intervention is that complications that arise during procedures may be more challenging to address (34). Complications during the treatment of liver injuries have been observed, resulting in hepatic necrosis (35). Furthermore, interventional radiology frequently manages the most severely ill patients within a hospital, occasionally as a final option. Hence, it is encouraged to explore the pitfalls, possible limitations and correct patient selection to improve clinical outcomes (38). The OFI in these interventions may be higher due to the complex nature of injuries.

Traumatic brain injury (TBI) is one of the most prevalent types of trauma. If not treated accurately, it can result in long-term cognitive, physical, and emotional impairments (25). The prognosis for TBI recovery varies depending on the severity of the injury. However, early interventions can significantly improve outcomes (39). If patients show signs of increased intracranial pressure, such as headaches, vomiting, confusion, or seizures, the medical team may consider performing intracranial pressure (ICP) measurements to monitor the patient's condition and guide treatment. In our study, providing this procedure was strongly associated with OFI (OR 5.29). Previous studies reported that ICP measurement increases the risk of mortality and complications. Variability in following protocols for ICP measurement is associated with an increased risk of mortality and morbidity, and quality improvement measurements are suggested to improve patient survival (40–42).

In severe cases of TBI, an emergency craniotomy may be necessary to reduce the ICP and prevent further damage to the brain. In this study, emergency craniotomy was the second most common intervention performed with high OR (3.82) for OFI. While we were unable to find comparable studies for direct comparison, other reports have shown that age and GCS score at the time of hospital admission is associated with poorer outcomes after craniotomy (42, 43).

External fracture fixation is typically done in cases of severe bone fractures where internal fixation is not possible, such as open fractures, fractures with significant soft tissue damage, or fractures that involve joints. This procedure was the third most common intervention in our study and had an OR 2.74 for OFI. Major fracture surgery was also significantly associated with OFI (OR 2.26). External fracture fixation is associated with a risk of bleeding, nerve or blood vessel damage, malalignment, or joint stiffness. Previous studies have reported a high incidence of infection after external fracture fixation (37, 38). Moreover, orthopedic injuries related to trauma in elderly patients are significantly associated with higher mortality (47).

The overall association between OFI and emergency procedures may not necessarily be due to the procedure itself but rather the specialized expertise and resources required for their performance. Studies have shown that interventions provided by full-time trauma surgeons are associated with lower mortality rates in patients with an ISS greater than 15 (41). Our data show that ISS is associated with an increase in OFI (OR 1.07), suggesting that patients with severe injuries are likelier to experience OFI than those with less severe injuries. Several factors might contribute to this association. A possible explanation is that patients with higher ISS have critical and complicated medical conditions requiring complex treatment and procedures. This complicated medical assessment might affect the medical decision-making resulting in adverse events and OFI. Hence, we hypothesize that these interventions may be associated with a higher risk of complications or errors if not performed immediately or appropriately.

In our study, OFI was found in 7.9% of the cases with trauma deaths. Although we found no significant difference in 30-day mortality between OFI and no-OFI patients, interestingly, the presence of OFI was significantly higher in patients who survived the trauma compared to those who died within 30 days after trauma. These observations suggest that the presence of OFI might have no impact on patient mortality. Another explanation for this finding could be that patients who survived trauma gained more OFIs during the care period later after 30 days, compared to patients who died within 30 days after trauma. We have not analyzed the difference between survivors and deceased individuals in relation to resuscitation alone or during, specifically, the first 30 days after trauma. We assume that the presence of OFI might result in morbidity but is not associated with mortality.

# Strengths and limitations

Being a retrospective study, our investigation has several limitations. As the study is retrospective register-based, we could not control the study outcomes and instead based our variables on records. This entails a risk that the recorded variables may be inaccurate. The retrospective inclusion of patients or data recording may result in selection bias with misclassification or information bias, and there can be residual confounding factors that were not considered in our analysis.

The study was conducted at a single center, which limits the generalizability of the findings to other settings.

While the inclusion of survivors provides essential insights into the effects of interventions in trauma care, the study lacks an analysis of the differences between survivors and deceased individuals in relation to resuscitation. Additionally, the specific types of OFI that occur during emergency procedures and their occurrence at different points in the treatment process have not been specified.

However, there are several strengths to this study that should be highlighted. One is that the study included a large patient cohort consisting of over 6,000 patients. This topic is not profoundly explored in previous literature, why it is difficult to find studies investigating comparable variables and study protocols. Nonetheless, the study provides new insights into factors predicting the presence of OFI.

# Clinical applications

The aim of the study was to investigate the presence of OFIs in trauma care and to identify the emergency procedures associated with OFIs in a large cohort of trauma patients from diverse demographics and backgrounds. Identifying OFIs in trauma care is crucial for improving patient outcomes, particularly during the early phase of trauma care. This study found that several emergency procedures were significantly associated with a higher risk of OFIs, including revascularization, radiological intervention, ICP measurement as sole intervention, craniotomy, and external fracture fixation. These findings suggest that careful consideration and monitoring of these procedures may reduce the incidence of OFIs in trauma patients. Additionally, the presence of OFI was directly related to patients with higher ISS scores and those who survived for more than 30 days after trauma.

# Future studies

Further studies on this topic are essential to ensure generalizability across diverse geographic regions and populations, such as multicenter studies, which would provide a more comprehensive understanding of the topic.

Our results indicate that performing interventions is associated with an increased risk of treatment errors. However, the specific nature of errors associated with these interventions, such as whether they involve procedural OFIs or system-related OFIs, was not analyzed in our study. The findings in this study indicate the need for further investigations to explore the relationships between the type of OFIs, the presence of OFIs during the trauma care course, and their relation to ISS.

# Conclusion

Radiological intervention, external fracture fixation, craniotomy, laparotomy for hemostasis, intracranial pressure measurement as the sole intervention, major fracture surgery, and revascularization were significantly associated with an increased risk of opportunity for improvement. Further investigation exploring the mechanisms of OFI during these interventions is needed.

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