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**Trauma cohorts and correlation do different opportunities for improvement**

***A registry based study***

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# Abstract

*Inledning*: Alla traumacenter som lever upp till level-1 standard enlig amerikansk standard, ska som del i förbättringsarbetet hålla i återkommande möten och dödfallsanalyser där patientfall diskuteras och granskas för möjligheter till förbättring. Hittills har få studier genomförts där man undersökt vilka förbättringsområden (Opportunities for improvement, OFI) som är vanligast förekommande för olika patientgrupper inom trauma. *Metod*: I denna studie har vi använt oss av data från Karolinskas universitetssjukhusets traumaregister och beräknat oddskvoten för fyra etablerade patientgrupper inom trauma att ha olika OFI. Vi har gjort detta via en multinominell, multivariabel regressionsmodell. *Resultat*: Vår studie visade att ”judgement error” var vanligast OFI (34%). Förbättringsområden kopplade till tekniska problem var minst vanliga (8,5%). Multitrauma utan traumatisk hjärnskada, var den största patientgruppen i studien och den som hade starkast statistisk koppling till alla specifika OFI (OR 6,48, 95% CI 4,38–9,60, p-värde <0,001). *Slutsats*: Vår studie ligger i linje med tidigare resultat som visat att ”judgement error” är den vanligaste orsaken till OFI, samtidigt som tekniska fel är mindre förekommande. Multitrauma utan hjärnskador hade högst oddskvot för OFI.

*Introduction*: As part of quality improvement programmes, level-1 trauma centres have recurring mortality and morbidity conferences where relevant disciplines and professions meet regularly to discuss and review patient cases for Opportunities for Improvement (OFI). Few studies have been made where different categories of trauma are assessed for OFI. *Method*: In Sweden, the Karolinska University Hospital is the only facility to qualify as a level-1 trauma centre according to American standards. In this study we have used data from the Karolinska University Hospital trauma care quality database to determine how different clinical trauma cohorts associate with specific OFI, using a multinominal multivariable regression model. *Results*: The most common OFI was error in judgement (34%). Technical error was least common (8.5%). Blunt multisystem trauma with traumatic brain injury was the largest cohort. It also had the most prominent association with error in judgement (OR 6.48, 95% CI 4.38-9.60, p-value <0.001). *Conclusion*: Our study supports previous finding of error in judgement as the dominating OFI and technical errors being rare. Blunt multisystem trauma without traumatic brain injury had the highest association to OFI.

*Keywords/MeSH:* Quality improvement, trauma centre, brain injury, blunt injury, decision-making

# Abbreviations

BM - Blunt multisystem trauma

TBI – Traumatic brain injury

ACS – American college of surgeons

TQIP - Trauma quality

M&M– Mortality and Morbidity

AIS – Abbreviated injury scale

OFI – Opportunity for improvement

# Introduction

### Trauma

Trauma, clinically defined as physical injury and the body´s associated response, is the most common cause of death in the first four decades of life. Trauma kills around 4.4 million people around the globe every year (1). In Sweden, almost 10,000 people suffer from severe trauma annually. (2) In the US, the American College of Surgeons (ASC) initiated the Trauma Quality Improvement Program (TQIP) in 2008 to improve trauma care quality and outcomes. The program provides medical staff with guidelines and recommendations on how to manage different patient populations and injury types. TQIP also collect data from trauma centres for benchmarking and report feedback. From 2017, the TQIP report benchmarks for ten patient cohorts, for which risk adjusted estimates for outcomes and complications are calculated and guidelines provided (3).

Multiple TQIP programs have been developed and implemented globally (4). To facilitate research, benchmarking, and implementation of guidelines, trauma patients are generally grouped according to injury or demographic characteristics (3). Broadly, trauma patients can be divided into two categories based on the mechanism of injury; penetrating (stab wounds or gunshots) and blunt ( e.g. car accidents, falls and interpersonal violence) (5). Overall, brain injury is the most common cause of trauma related death, counting for 58.6 percent of all trauma deaths in Sweden (6). In 2021, 62 percent of patients passing from blunt violence in Sweden did so due to damage of the brain. The equivalent figure for patients with penetrating trauma was 22 percent (6). Traumatic brain injury (TBI) is thus highly associated with fatal outcome and is weighing on mortality statistics of both blunt and penetrating patient groups (7,8).

*AIS score*

For more precise categorisation of trauma injuries, the abbreviated injury scale (AIS) has been implemented. The AIS-system is presented as a seven-digit number where each position derives to specific information on the injury. The first number indicates the body region (head, extremity etc) and the second type of anatomic structure (muscle, skeletal etc.). The following two-digit number tells the specific anatomic structure (e.g. femur). The two digits after that indicate the level of injury and the final, single number, the severity of injury on a 6-point scale (9,10). The TQIP cohorts implemented by ACS are defined using the AIS-system. For instance, patients included in the blunt multisystem cohort have a severity score of at least 3 in at least two of the following body regions: head, face, neck, thorax, abdomen spine, upper, or lower extremity (3). TBI is further defined as an AIS severity-score of at least 3 in the head region, a GCS of maximum 8 at arrival to the emergency room and no other injures with a severity-score higher than two in any other AIS body region (3).

### Trauma system

A trauma system is a coordinated network of healthcare providers and resources designed to provide timely and effective care to patients with traumatic injuries. Trauma systems have a long tradition within the military but were not implemented in civil health care until the 1960s-1970s when the report “Accidental Death and Disability: The Neglected Disease of Modern Society” was published in the US (11). Since then, trauma systems have been put into practice in most western countries, improving mortality and morbidity for severely injured patients (12). The ACS provides guidelines for how the system should be structured. In general, the system consists of four components: (i) pre-hospital care, (ii) hospital care at a trauma centre, (iii) post-hospital care and (iv) injury prevention. Continuous quality improvement and evaluation are also essential to the trauma system and should be systematically performed at all levels (12).

*Trauma centres*

Trauma centres are specialised medical facilities designed to quickly respond to the need of patients with critical physical injury. The ACS has outlined specific criteria for five different levels of trauma centres, where each level refers to the kind of resources available and number of patients admitted yearly. Level-1 trauma centres provide the highest level of care and are equipped for every aspect of injury round the clock with operating rooms, standby trauma teams, imaging and well-stocked blood banks etc. (13,14) The trauma team is ideally composed by an airway specialist with an assistant nurse, one assessing doctor, one treating doctor and two nurses responsible for circulation and monitoring. The team is led by a clinician or doctor with the highest level of trauma care skills, who manages and controls resuscitation of the patient hands off (15). In addition to medical resources, level-1 trauma centres should engage in quality assessments and improvement programs for trauma care. (14)

*M&M conferences*

and Morbidity (M&M) conferences are recurring meetings where a multidisciplinary team of qualified surgeons, anaesthesiologist and nurses perform a peer review of selected patient cases to establish whether death could have been prevented and/or any other errors in the care have occurred. The members of the multidisciplinary team are assigned by the hospital and should not have participated in the direct care of the patient in question (16). The aim of the conference is to identify opportunities for improvement and subsequent actions that can be taken to improve future care (17). Conducting M&M-conferences within 30 days after trauma has been used as a quality measure of care, and should be an integrated part of care at all level-1 trauma centres (18).

### Opportunities for improvement

Opportunities for improvement (OFI) is an established concept within trauma care evaluation and can be defined as all deficiencies or aberrations from guidelines at any stage of care in a trauma system that could have been avoided through optimised action (19). Teixeria et al. and O’Reilly have compiled categories of specific OFI recurrent within trauma care: Clinical judgement error (inadequate monitoring of patients, e.g. medication errors) , delay in treatment (operation/ other intervention) , missed injury and technical errors (e.g.. (20,21).

In events where trauma leads to death, mortality can be categorised as either possibly preventable, preventable or non-preventable, where preventable mortality is defined as loss of life that likely would have been avoided if one or more errors in the trauma system would have been corrected (22). More specifically, *(1)* the injuries of the patients must have been survivable, *(2)* the care delivered has been suboptimal and *(3)* the errors in care can be directly or indirectly derived to the death of the patient (17,18).

### Current landscape

To date, a variety of studies based on OFI have been conducted with the aim to identify recurrent errors for specific patient cohorts or trauma facilities. Socioeconomic, cultural and geographic issues, as well as trauma characteristics and healthcare vary between countries and rural/city areas (23,24). In Sweden surgical care is highly centralised and no uniform national organisation for trauma care is at place. This makes evaluation of competence and performance at site crucial to maintain high quality and avoid unnecessary risks for the patient (25). Sweden further stand out from other western countries with cold climate, fewer cases of serious trauma annually and long distances to trauma centres, as few hospitals are equipped to treat level-1 trauma patients (24,26).

These unique characteristics complicate direct translation of results from trauma studies in other economically similar countries to Swedish context. Nordic countries have further been falling behind when it comes to studies on trauma. In the years 2005-2018, 29 trauma studies were published per million residents in Sweden (compared with 52/million in Norway). Of these, only 3% were focused on trauma systems and trauma registers (24).

The trauma care quality database at the Karolinska University Hospital is the most comprehensive registry of serious trauma in Sweden. For instance, information on e.g., OFI reported form M&M-conferences at the hospital according to American standards are included, which facilitates comparison with data internationally. Previous studies of the trauma care quality database have focused on OFI related to preventability of death (6,25). While this gives paints a picture of the most fatal errors, it neglects all OFI related to non-fatal errors in care. Previous studies have also not studied OFI for different patient cohorts. Trauma is a heterogenous term, covering all types of physical injury in terms of mechanism and patient characteristics. A young patient suffering penetrating trauma requires separate care from an older patient with TBI. To provide sufficient guidance on specific actions to improve trauma care, different trauma cohorts should be evaluated separately for OFI. To date, little research has been done on specific OFI related to different trauma cohorts.

## Aim:

The aim of this study is to determine how different clinical trauma cohorts associate with specific OFI.

## Material and Methods:

## Study design

We conducted a registry-based cohort study using data from SweTrau and the trauma care quality database at the Karolinska University Hospital. We analysed the data using a multinominal multivariable logistic regression model to assess how clinical cohorts associate with specific OFI.

## Setting

From 2010, The Swedish Trauma society holds a national registry (SweTrau) over patients suffering serious trauma in Sweden. Patients included in the registry have suffered traumatic events that have either triggered trauma team activation or generated injuries with a new injury severity score (NISS) above 15. Patients where subdural hematoma is the only traumatic injury and cases that have triggered a trauma alarm without underlying trauma are excluded. There is no automatic registration of patient data to SweTrau, since no integrated journal system is implemented in Sweden (2).

The Karolinska University Hospital is the only qualified level-1 trauma centre in Sweden according to ACS standards (14,27). The hospital is located in Stockholm county, but accounts for the regions of Stockholm, Gotland, Södermanland and Västmanland, adding up to 3 million residents, which is just on pair with minimum quantity according to American standards (27). All patients treated at the Karolinska University Hospital and who have either triggered trauma team activation or had an injury severity score (ISS) of > 9 in the emergency room are stored in a local, quality database. Data of patients that also qualify for SweTrau are reported and included in there.

As part of level-1 criteria, multidisciplinary M&M conferences are held regularly at the Karolinska University Hospital to evaluate treatment of patients and identify specific OFI. The multidisciplinary board is appointed by the hospital and consists of a surgeon, an anaesthetist, a trauma nurse and in presence of specific injuries (e.g., intracranial, orthopaedical or thoracic/vascular), specialists from appropriate specialties. Competences involved in the direct care of the patient are free to attend the conference but should not take part in the review (18).

Patients are selected for conference in a multistage process with escalating levels of reviews. All cases of mortality are passed directly to conference, where the cause of death and whether it was preventable or possibly preventable is decided. The review is then followed by identification of OFI. The review process for non-mortality poor-outcomes has been subsequently improved and formalised. In the years 2014-2017, trauma patients were somewhat randomly selected and individually reviewed by a specialised trauma nurse who made the call weather patients should be escalated to conference. In 2017, the procedure was therefore formalised with the introduction of audit filters.

Audit filters, listed in table 1, are specified conditions that all trauma patients are automatically evaluated by. Patients captured by one or more audit filters are then assessed by a nurse who identifies possible gaps in care. If the first nurse identifies any potential issues, the patient is reviewed in a second round by two specialised nurses. If any OFI are identified in the second round, the patient is brought to a M&M conference for a final assessment of OFI (18). Results from the conference are stored as specific OFI in the Karolinska University hospital’s trauma care quality database. Figure 1. illustrates the processes of OFI assessment.

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| **Table 1.** Audit filters |
| * Systolic blood pressure < 90 * Glasgow coma scale < 9 and not intubated * Injury severity score > 15 but not admitted to the intensive care unit * Time to acute intervention > 60 minutes from arrival to hospital * Time to computed tomography > 30 minutes from arrival to hospital * No anticoagulant therapy within 72 hours after TBI * 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 |
| *Table 1.* Audit filters used to screen patients at the Karolinska University Hospital. Patients captured by one or more filters are reviewed by a nurse for errors in treatment. |
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| **Figure 1.** Flowchart desdcribing the exclusions made and the process of truama cases from arrivel untill OFI decision. |
| En bild som visar diagram  Automatiskt genererad beskrivning |
| *Figure 1*. The upper part of the chart describes exclusion of patients from the Karolinska University Hospital trauma care quality database. All patients under the age of 15 and those not screened for OFI were excluded. The bottom part discribes the processes of OFI identification for patients included in anlaysis. All patients in the study have either been flagged by one or more auditfilters or by a nurse, and then esclated to a M&M conference. All cases with fatal outcome were automatically brought to conference. |
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## Study population

We studied data of patients from the Karolinska University Hospital registered in SweTrau. Patients included met the following criteria:

* Older than 15 years
* A NISS > over 15
* Being reviewed at an M&M conference at the Karolinska University Hospital

## Variables

The outcome was specific OFI identified by the M&M-conference at the Karolinska University hospital. The OFI were grouped into 5 categories of improvement similar to Teixeria et al (21) and O’Reilly (20), presented in Table 2. Preventable death was included as an OFI for patients passing within 30 days after trauma. The OFI included deaths that were assessed as preventable or potentially preventable at conference. These two categories were grouped into one variable, as each category on its own contained few patients. Finally, “no OFI”, was included in cases where no OFI were identified at conference. Only the dominating OFI from conference was counted, each patient was thus only presented once.

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| **Table 2.** Specific OFI | | | | | | | | |
| Judgement error | Delay | Diagnosis | Technical | | Other | No OFI | Preventable |
| Shortage of competence  Wrong level of care  Problem with triage at ED  Error in administration/decision-making | Long time to operation | Missed injury,  Long time to CT | Error in logistics or technique | Problem with trauma criteria,  Error in documentation,  Communication,  Problem with tertiary survey,  Error in routine  No neurosurgeon at site  Problem with resources | | No OFI identified | Preventable  or possibly preventable death |
| *Table 2.* All specific OFI identified at the Karolinska University Hospital M&M conference categorised. | | | | | | | | |

The independent variables were patient cohorts grouped by injury characteristics using the AIS grading system. The inclusion criteria for the four cohorts in this study are listed below (9).

1. *Isolated severe TBI*: Injury isolated to the head region with an AIS-severity score ≥ 3 and:
   1. A pre-or in hospital GCS of <9

or

* 1. Pre – or in hospital intubation
  2. All patients with an AIS-severity score >2 in any other body region were excluded from the cohort.

1. *Blunt multisystem trauma with TBI*: Blunt trauma with AIS-severity score ≥ 3 in at least two of the following AIS body regions: head, face, neck, thorax, abdomen, spine, or upper and lower extremities, AND
   1. A pre-or in hospital GCS of <9

and

* 1. An AIS-severity score ≥ 3 in the head region

1. *Blunt multisystem trauma without TBI*: Blunt trauma with AIS-severity score ≥ 3 in at least two of the following AIS body regions: head, face, neck, thorax, abdomen, spine, or upper and lower extremities. All patients with:
   1. An AIS-severity score ≥ 3 in the head region

and

* 1. A pre-or in hospital GCS of <9

Were excluded.

1. *Penetrating trauma*:At least one AIS-severity score ≥ 3 injury in any of the following AIS body regions: neck, thorax, and abdomen. Penetrating had also been registered as the mechanism of injury.

All patients who did not qualify into one of the four cohorts, where assigned a fifth category, called “other cohort.” Gender, age, NISS were used in an adjusted model. All variables were categorical, except for age which was numerical.

## Data sources/measurement

Data on AIS-score, age, NISS, gender, GCS-score and intubation were available from SweTrau. The OFI variable was created from the Karolinska University Hospital database.

## Study size

A total of 11,864 patient where registered in both SweTrau and the trauma care quality database at the Karolinska University hospital in the years 2017-2022. From these, 5,556 patient who had not been screened for OFI, were excluded. All patients under the age of 15 were also excluded, leaving a total of 6,310 patients for analysis (Figure 1).

## Statistics

All data was processed and analysed in statistical programming software R. Data from SweTrau and the Karolinska University Hospital trauma care quality database were extracted and merged based on patient ID. Descriptive statistics were used to describe the study sample. A multinomial multivariable regression model was then constructed with seven categories of specific OFI as the dependent variable, explained by five patient cohorts as independent variables. Both an unadjusted model and a model adjusted for age, gender and NISS were created.

The models estimate the odds ratio (OR) of each category of specific OFI for each patient cohort. “No OFI” was set as reference for the dependent variable and “Other cohort” for the explanatory variable. The coefficients should hence be interpreted as the log odds for each category of OFI occurring for each patient cohort compared with other cohort having no OFI. To obtain the odds ratio, the coefficients were exponentiated.

Z-values were calculated to assess statistical significance, with the null-hypothesis that there are no association between the evaluated category of specific OFI and the patient cohort. A p-value of 0.005 (z-value > 1,96) was considered significant to reject the null-hypothesis.

## Bias

To prevent bias, the multivariable regression model was developed using a simulated scrambled dataset with random data. The algorithm for the model was developed step-by-step and then evaluated by a trained programmer and statistician before being applied on the real data.

## Ethical considerations

The study required ethical permit and has been approved 2021-02541 and 2021-03531. All variables such as ID-number and name were scrambled and anonymised throughout analysis of the real dataset. In addition to protecting patients’ integrity, this also prevented discrimination and bias, as alll models for analyses were design without access to real data. One potential risk of violating patient integrity was the small number of patients within each cohort attributed with an OFI. However, to identify an individual in the dataset would require specific knowledge about the patient and the care process. Potential harm of patients included in the study is therefore low. Moreover, this study improves understanding of gaps in trauma care, which may contribute to future quality improvements that ultimately save lives.

# Results

Of the 6,310 patients in our study, 336 patients were excluded because they lacked data in variables necessary for cohort categorisation. Table 3. Shows the number and share of patients missing values in each variable. Since one patient could have missing values in more than one variable, the table adds up to 338. In the end, 5,794 patients were analysed for specific OFI.

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| **Table 3.** Missing data | | |
|  | Amount | Percentage |
| Alive | 12 | 0.19 |
| Age | 0 | 0.00 |
| Gender | 0 | 0.00 |
| OFI | 0 | 0.00 |
| NISS | 8 | 0.13 |
| Log GCS | 317 | 5.02 |
| Intubated | 1 | 0.02 |
| *Table 3.* Number of patients and percentage of all patients included in the study with missing data in each variable. | | |

*Cohort demographics*

Table 4. shows demographics of all patient cohorts. Blunt multisystem (BM) without traumatic brain injury (TBI) was the largest cohort of study (498). Men were overrepresented in all cohorts (69.2%), but most prominently in penetrating trauma where 91.3% were men. This cohort was also characterised by younger age, with a median of 27 years, compared with an overall median of 42 years. 508 patients died within 30 days after trauma. Patients with TBI (isolated TBI and BM with TBI) had higher mortality (54.5% and 53.2% respectively) compared average mortality of 8.5% for all cohorts. Average NISS was also higher for patients with TBI, 40.2 and 49.6 respectively, compared with 30.0 and 33.3 for penetrating trauma and BM without TBI.

*Demographic distribution across specific OFI*

Table 5. presents the distribution of cohorts and patients demographics across all seven categories of specific OFI. Overall, OFI were identified in 400 (6.7%) of the patient cases. The most common was error in judgement, 136 (34%). Technical error was least common, 34 (8.5%). Of 508 deaths that occurred within 30 days of trauma, 25 (4.9%) were deemed preventable. Median age for preventable death was 69 years, which was higher than for other OFI. Gender distribution was equal across all OFI.

*Risk ratios for cohorts and specific OFI*

Table 6.shows the unadjusted odds ratios for each patient cohort and category of specific OFI compared with the “other cohort” having no OFI. The cohort that stood out was BM without TBI, which had significantly higher odds ratio of any category of OFI compared with other cohort having no OFI. Of 498 patients with MB without TBI, 42 had an error in judgement (Table 3.) (OR 6.48, 95% CI 4.38-9.60, p-value <0.001). The cohort also had higher odds ratio of experiencing delays (OR 4.15, 95% CI 1.84-9.39, p-value <0.001), technical issues (OR 3.81, 95% CI 1.61-9.01, p-value 0.002) and other OFI such as faults in communication, documentation, or resources (OR 4.33, 95% CI 2.70-6.93, p-value <0.001). Association with preventable death was (OR 6.23, 95% CI 2.29-16.19, p-value <0.001)

BM with TBI had less significant results. Most prominent was high odds ratio of preventable death (OR 7.25, 95% CI 2.00-26.2, p-value 0.003). The cohort was also associated with delays in treatment (OR 3.62, 95% CI 1.07-12.2, p-value 0.038). So were patients with isolated TBI (OR 4.47, 95% CI 1.52-13.1, p-value 0.006). Patients suffering severe penetrating trauma had higher odds ratio of technical errors (OR 3.16, 95% CI 1.08-9.27, p-value 0.036), error in judgement (OR 2.69, 95% CI 1.44-5.01, p-value 0.002) and preventable death (OR 4.53, 95% CI 1.26-16.3, p-value 0.053).

After adjusting for age, gender and NISS, statistical association between BM without TBI and delays, missed diagnosis, judgement error, and other OFI remained. The ORs for NISS, age and gender, with female set to reference, were approximately 1 for all categories of OFI, implying small explanatory value. Statistical significance association on a 0.05 level was however lost for all other cohorts and OFI. This could in part be explained by less data in these groups.

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| **Table 4.** Cohort demographics | | | | | | |
|  | **BM with TBI** | **BM without TBI** | **Isolated TBI** | **Other cohort** | **Penetrating** | **Overall** |
|  | (N=186) | (N=498) | (N=202) | (N=4788) | (N=300) | (N=5974) |
| **Dead at 30 days** |  |  |  |  |  |  |
| Yes | 99 (53.2%) | 73 (14.7%) | 110 (54.5%) | 161 (3.4%) | 65 (21.7%) | 508 (8.5%) |
| No | 87 (46.8%) | 425 (85.3%) | 92 (45.5%) | 4627 (96.6%) | 235 (78.3%) | 5466 (91.5%) |
| **Age** |  |  |  |  |  |  |
| Mean (SD) | 45.1 (20.3) | 51.3 (21.3) | 56.4 (22.6) | 44.7 (21.2) | 31.6 (13.8) | 45.0 (21.3) |
| Median [Min, Max] | 42.0 [15.0, 94.0] | 51.0 [15.0, 97.0] | 59.5 [15.0, 97.0 | 42.0 [15.0, 100] | 27.0 [15.0, 90.0] | 42.0 [15.0, 100.0] |
| **Gender** |  |  |  |  |  |  |
| Female | 58 (31.2%) | 144 (28.9%) | 51 (25.2%) | 1563 (32.6%) | 26 (8.7%) | 1842 (30.8%) |
| Male | 128 (68.8%) | 354 (71.1%) | 151 (74.8%) | 3225 (67.4%) | 274 (91.3%) | 4132 (69.2%) |
| **Severe TBI1** |  |  |  |  |  |  |
| Not Severe | 0 (0%) | 293 (58.8%) | 0 (0%) | 4262 (89.0%) | 276 (92.0%) | 4831 (80.9% |
| Severe | 186 (100%) | 205 (41.2%) | 202 (100%) | 526 (11.0%) | 24 (8.0%) | 1143 (19.1%) |
| **ED GCS** |  |  |  |  |  |  |
| Mean (SD) | 5.37 (2.15) | 13.8 (2.39) | 4.90 (1.77) | 14.4 (1.66) | 14.1 (2.61) | 14.1 (2.41) |
| Median [Min, Max] | 5.00 [3.00, 8.00] | 15.0 [5.00, 15.0] | 4.00 [3.00, 8.00 | 15.0 [3.00, 15.0] | 15.0 [3.00, 15.0] | 15.0 [3.00, 15.0] |
| Missing | 137 (73.7%) | 32 (6.4%) | 80 (39.6%) | 68 (1.4%) | 59 (19.7%) | 376 (6.3%) |
| **Intubated** |  |  |  |  |  |  |
| In-hospital | 39 (21.0%) | 99 (19.9%) | 100 (49.5%) | 214 (4.5%) | 72 (24.0%) | 524 (8.8%) |
| Not intubated | 9 (4.8%) | 367 (73.7%) | 21 (10.4%) | 4505 (94.1%) | 169 (56.3%) | 5071 (84.9% |
| Prehospital | 138 (74.2%) | 32 (6.4%) | 81 (40.1%) | 69 (1.4%) | 59 (19.7%) | 379 (6.3%) |
| **NISS** |  |  |  |  |  |  |
| Mean (SD) | 49.6 (14.9) | 33.3 (11.9) | 40.2 (15.8) | 9.97 (9.64) | 30.0 (20.3) | 15.2 (15.5) |
| Median [Min, Max] | 49.0 [19.0, 75.0] | 29.0 [18.0, 75.0] | 38.0 [9.00, 75.0] | 6.00 [0, 75.0] | 22.0 [9.00, 75.0] | 11.0 [0, 75.0] |
| *Table 4.* 1 Severe TBI is defined as injury to the head with an AIS >3. BM patients with severe TBI and GCS<9 were categorised as BM with TBI. BM patients with severe TBI and GCS >9 were categorised as BM without TBI. This distinction was made to avoid overlap. | | | | | | |

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| **Table 5.** OFI demographics | | | | | | | | |
|  | **Delays** | **Diagnosis** | **Judgement error** | **No OFI** | **Other OFI** | **Preventable** | **Technical** | **Overall** |
|  | (N=40) | (N=68) | (N=136) | (N=5574) | (N=97) | (N=25) | (N=34) | (N=5974) |
| **Cohort** |  |  |  |  |  |  |  |  |
| BM1 with TBI1 | 3 (7.5%) | 4 (5.9%) | 2 (1.5%) | 171 (3.1%) | 2 (2.1%) | 3 (12.0%) | 1 (2.9) | 186 (3.1%) |
| BM without TBI | 80 (20.0%) | 12 (17.6%) | 42 (30.9%) | 398 (7.1%) | 25 (25.8%) | 6 (24.0%) | 7 (20.6%) | 498 (8.3%) |
| Isolated TBI | 4 (10.0%) | 2 (2.9%) | 185 (3.3%) | 185 (3.3%) | 2 (2.1%) | 2 (8.0%) | 1 (2.9%) | 202 (3.4%) |
| Severe penetrating | 3 (7.5.%) | 2 (2.9%) | 12 (8.8%) | 274 (4.9%) | 2 (2.1%) | 3 (12.0%) | 4 (11.8%) | 300 (5.0%) |
| Other cohort | 22 (55.0%) | 48 (70.6%) | 74 (54.4%) | 4546 (81.6%) | 66 (68.0%) | 11 (44.0%) | 21 (61.8%) | 4788 (80.1%) |
| **Dead at 30 days** |  |  |  |  |  |  |  |  |
| Yes | 0 (0%) | 0 (0%) | 0 (0%) | 483 (8.7%) | 0 (0%) | 25 (100%) | 0 (0%) | 508 (8.5%) |
| No | 40 (100%) | 68 (100%) | 136 (100%) | 5091 (91.3%) | 97 (100%) | 0 (0%) | 34 (100%) | 5466 (91.5%) |
| **Age** |  |  |  |  |  |  |  |  |
| Mean (SD) | 43.0 (19.8) | 45.9 (21.7) | 51.5 (21.5) | 44.8 (21.2) | 46.0 (20.8) | 59.9 (23.7) | 40.1 (17.2) | 45.0 (21.2) |
| Median [Min, Max] | 37.5 [15.0, 86.0] | 44.0 [15.0, 86.0] | 54.0 [15.0, 97.0] | 42.0 [15.0, 100] | 44.0 [15.0, 97.0] | 69.0 [19.0-95.0] | 40.5 [16.0, 74.0] | 42.0 [16.0, 74.0] |
| **Gender** |  |  |  |  |  |  |  |  |
| Female | 10 (25.0%) | 22 (32.4%) | 39 (28.7%) | 1733 (31.1%) | 26 (26.8%) | 5 (20.0%) | 7 (20.6%) | 1842 (30.8%) |
| Male | 30 (75.0%) | 46 (67.6%) | 97 (71,3%) | 3841 (68.9%) | 71 (73.2%) | 20 (80.0%) | 27 (79,4%) | 4132 (69.2%) |
| **Severe TBI** |  |  |  |  |  |  |  |  |
| Not Severe | 30 (75.0%) | 56 (82.4%) | 84 (61.8%) | 4552 (81.7%) | 76 (78.4%) | 14 (56.0%) | 19 (55.9%) | 4831 (80.9%) |
| Severe | 10 (25.0%) | 12 (17.6%) | 52 (38.2%) | 1022 (18.3%) | 21 (21.6%) | 11 (44.0%) | 15 (44.1%) | 1143 (19.1%) |
| **ED GCS** |  |  |  |  |  |  |  |  |
| Mean (SD) | 13.0 (3.24) | 14.0 (2.32) | 13.8 (2.70) | 14.1 (2.39) | 14.4 (1.52) | 11.3 (5.04) | 13.6 (2.28) | 14.1 (2.41) |
| Median [Min, Max] | 15.0 [3.00, 15.0] | 15.0 [5.00, 15.0] | 15.0 [3.00, 15.0] | 15.0 [3.00, 15.0] | 15.0 [6.00, 15.0] | 14.0 [3.00, 15.0] | 15.0 [7.00, 15.0] | 15.0 [3.00, 15.0] |
| Missing | 2 (5.0%) | 5 (7.4%) | 2 (1.5%) | 361 (6.5%) | 2 (2.1%) | 4 (16.0%) | 0 (0%) | 376 (6.3%) |
| **Intubated** |  |  |  |  |  |  |  |  |
| Inhospital | 13 (32.5%) | 10 (14.7%) | 15 (11.0%) | 453 (8.1%) | 12 (12.4%) | 12 (48.0%) | 9 (26.5%) | 524 (8.8%) |
| Not intubated | 25 (62.5%) | 53 (77.9%) | 119 (87.5%) | 4757 (85.3%) | 83 (85.6%) | 9 (36.0%) | 25 (73.5%) | 5071 (84.9%) |
| Prehospital | 2 (5.0%) | 5 (7.4%) | 2 (1.5%) | 364 (6.5%) | 2 (2.1%) | 4 (16.0%) | 0 (0%) | 379 (6.3%) |
| **NISS** |  |  |  |  |  |  |  |  |
| Mean (SD) | 24.6 (12.6) | 18.7 (12.6) | 25.5 (11.5) | 25.5 (11.5) | 20.1 (12.1) | 36.5 (19.4) | 25.1 (12.3) | 15.2 (15.5) |
| Median [Min, Max] | 22.0 [1.00, 57.0] | 17.0 [1.00, 66.0 | 25.0 [2.00, 66.0] | 10.0 [0, 75.0 | 19.0 [1.00, 50.0 | 34.0 [4.00, 75.0] | 28.0 [1.00, 45.0] | 1.0 [0, 75.0] |
| *Table 5.* Distribution of cohorts and patient demographics across specific OFI. 1 BM= Blunt multisystem trauma, TBI = Traumatic brain injury | | | | | | | | |

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 6. – Odds ratios** | | | |
| **Characteristics** | * **OR1** | * **95% CI1** | * **p-value** |
| Delays |  |  |  |
| * Other cohort | * - | * - | * - |
| * BM with TBI2 | * 3.62 | * 1.07, 12.2 | * 0.038 |
| * BM without TBI | * 4.15 | * 1.84, 9.39 | * <0.001 |
| * Isolated TBI | * 4.47 | * 1.52, 13.1 | * 0.006 |
| * Penetrating | * 2.26 | * 0.67, 7.60 | * 0.2 |
| Diagnosis |  |  |  |
| * Other cohort | * - | * - | * - |
| * BM with TBI | * 2.22 | * 0.79, 6.21 | * 0.13 |
| * BM without TBI | * 2.86 | * 1.50, 5.42 | * 0.001 |
| * Isolated TBI | * 1.02 | * 0.25, 4.25 | * >0.9 |
| * Penetrating | * 0.69 | * 0.17, 2.86 | * 0.6 |
| Judgement error |  |  |  |
| * Other cohort | * - | * - | * - |
| * BM with TBI | * 0.72 | * 0.18, 2.95 | * 0.6 |
| * BM without TBI | * 6.48 | * 4.38, 9.60 | * <0.001 |
| * Isolated TBI | * 1.99 | * 0.86, 4.64 | * 0.11 |
| * Penetrating | * 2.69 | * 1.44, 5.01 | * 0.002 |
| Technical |  |  |  |
| * Other cohort | * - | * - | * - |
| * BM with TBI | * 1.27 | * 0.17, 9.47 | * 0.8 |
| * BM without TBI | * 3.81 | * 1.61, 9.01 | * 0.002 |
| * Isolated TBI | * 1.17 | * 0.16, 8.75 | * 0.9 |
| * Penetrating | * 3.16 | * 1.08, 9.27 | * 0.036 |
| Preventable |  |  |  |
| * Other cohort | * - | * - | * - |
| * BM with TBI | * 7.25 | * 2.00, 26.2 | * 0.003 |
| * BM without TBI | * 6.23 | * 2.29, 16.9 | * <0.001 |
| * Isolated TBI | * 4.47 | * 0.98, 20.3 | * 0.053 |
| * Penetrating | * 4.53 | * 1.26, 16.3 | * 0.021 |
| Other OFI |  |  |  |
| * Other cohort | * - | * - | * - |
| * BM with TBI | * 0.81 | * 0.20, 3.32 | * 0.8 |
| * BM without TBI | * 4.33 | * 2.70, 6.93 | * <0.001 |
| * Isolated TBI | * 0.74 | * 0.18, 3.06 | * 0.7 |
| * Penetrating | * 0.50 | * 0.12, 2.06 | * 0.3 |
| *Table 6.* OR1 = Odds Ratio, CI = Confidence Interval. Other cohort and No OFI were set as reference. BM 2 = Blunt multisystem, TBI = Traumatic brain injury. | | | |

# Discussion

*Error in judgement*

The most common category of specific OFI was error in judgement. This is in line with findings of Ghorbani and Strömmer who analysed preventable death at the Karolinska University Hospital in 2012-2016. They found judgment error to be the most common error in both preventable and non-preventable deaths (14.9%) (28). Similar results have been reached in the US. When Teixera et al. studied preventable deaths in a level-1 trauma centre the years 1998-2005, 21.6% could be associated to clinical judgement errors, where most related to inadequate patient monitoring (52.9%) (21). Equally, Matsumoto at el. found that 90.5% of all preventable and possibly preventable deaths at University of California San Diego in 2000-2014, could be derived to errors in judgement (29). Our study also showed that errors related to technical issues were uncommon, which agrees with previous research (8,20,21,29–31). Thus, while OFI derived from technical errors seem to have declined with advancement in technology, errors related to human decision making prevail.

*BM without TBI – the largest cohort*

BM without TBI was the dominating cohort across all categories of OFI. It was also the largest cohort in the study. One possible explanation is the higher risk of death related to TBI. This thesis is supported by higher NISS and mortality within 30 days of trauma for patients with TBI (both isolated and in BM with TBI) (table 3). Further, if death occurs close after injury, the patient may have died before any OFI can arise. Injury mortality is typically described with trimodal distribution; immediate deaths at scene, early deaths due to haemorrhage and late deaths from organ failure (32). A review by Sobrino and Shafi on timing and cause of death after injury showed that brain injury is highly associated with immediate death (33). However, when adjusting for death on arrival, Ghorbani and Strömmer found that mortality related to TBI increased and that most TBI related deaths occur later (28). The high association between BM without TBI and error in judgement is however conspicuous and should be further investigated.

*Isolated TBI and BM with TBI*

BM with TBI was highly associated with preventable death. Contrarywise, there was no association between isolated TBI and preventable death. This could be due to higher age in this cohort, which has been shown to serve as an independent predictor of worse outcomes in TBI (34–36). In the US, mortality rates for TBI-patients aged 65 or older were at least twice as high compared with any younger age group (35,36). Higher risk of preventable death for BM with TBI may further be a product of the complex injury picture presented with this patient group, contributing to ambiguity that may complicate decision-making and treatment. For instance, severely injured patients with acute traumatic coagulopathy require massive transfusions, but few studies have been made on how this affects patients who also have TBI (37).

*Delay in time to operation*

Both isolated TBI and BM with TBI were significantly associated with delay in time to operation compared with other cohorts (Table. 6). This is in accordance with several studies reporting delay in evacuation of intracranial hematoma as the most common error leading to preventable death in patients with TBI (38,39). However, in a study review of time to surgery for TBI patients, it has been argued that rapid triage, early diagnosis and neurosurgical consultation are more important in improving patient outcomes (38). Delay in time to operation might thus be a latent error caused by previous discrepancies in care (20). When O’Reilly studied patients who died from haemorrhage after trauma, OFI related to decision between surgery, radiology and further investigation were most common (20). Further research to determine reasons for delay in time to surgery is needed.

**Limitations**

This study was limited to level-1 trauma patients treated at the Karolinska University Hospital. Since the hospital is the only trauma centre in Sweden living up to American standards, it diverges from other trauma facilitates in Sweden. Consequently, results from this study cannot be directly translated to other trauma care providers in the country. Further, the majority of traumatic injures treated in Swedish hospitals are not level-1 traumas (40), which is the only degree of trauma studied in this thesis.

The studied data is highly dependent on appropriate documentation and continuity in registration. Before the introduction of audit filters in 2017, patients were randomly selected for reviewed at the Karolinska University Hospital. Although the process of selection has been formalised since then, assessment for OFI is still dependent on people conducting the review, leaving room for subjectivity and errors in judgment.

The study was also weakened by data size. Although 6,310 patients were eligible for study after inclusion criteria, only 1,186 patients were fitted into one of the cohorts of interest. Of these, 400 were identified with a specific OFI. The number of patients within each category of OFI were thus scares in some cases, leading to considerable uncertainty. Lastly, only the OFI judged the most critical was available for each patient, why latent errors and interactions between errors could not be studied for patient with more than one OFI.

**Strengths**

The Karolinska University Hospital trauma care quality database is the most robust and detailed registry of trauma patients in Sweden. Moreover, patient data is registered according to ACS standards, providing sufficient comparability with international data.

This study is unique in assessing OFI dependent on patient cohorts. The cohorts were further established based on definitions recognised by the ACS, enabling comparison with international data. To avoid previous overlap between cohorts, we distinguished between blunt multisystem trauma with and without TBI. Our study show that OFI differ between patient cohorts, pointing at the need for sperate evaluation and interventions for different trauma cohorts. Finally, the Karolinska University Hospital covers a large geographical area, treating more trauma patients than any other hospital in Sweden. Results from this study can be directly translated and used for further research to ultimately improve trauma care for future patients treated at the hospital.

**Clinical application**

Our study confirms previous findings of error in judgement as the dominating OFI within trauma care. We have also found that BM without TBI is the cohort most prone to make judgement errors. As clinicians, we need to be cognisant of this and increase our alertness to potential issues. More research is needed to identify potential reasons for poor decision-making.

# Conclusion

Error in judgement is the most common OFI, while technical errors are rare. BM patients without TBI had the highest association to all OFI compared with other cohorts in the study, most prominent was error in judgement.

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