

**Trauma cohorts and correlation to specific opportunities for improvement**

**A registry based study**

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# Abstract

Trauma includes a wide set of patient characteristics, both with respect to mechanism of injury and patient demographics. Different categories of trauma require different care and health care workers are thus confronted with the challenge do make the correct calls and provide adequate care in each specific case. As part of quality improvement of care, all level-1 trauma centres should have recurring M&M conferences where relevant disciplines and professions meet regularly to discuss and review patient cases for OFIs. 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 quality database at Karolinska to assess four patient groups common within trauma or association with specific OFIs. Our study supports previous results of judgement error as the dominating cause of non-optimal care. The patients group with strongest association to this OFI is blunt multisystem trauma without traumatic brain injury.

# Abbreviations

BM - blunt multisystem

TBI – Traumatic brain injury

KUH – Karolinska University hospital

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 (3). In Sweden, almost 10,000 people suffer from severe trauma annually. (4) 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 trauma care providers 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 on 10 patient cohorts, for which risk adjusted estimates for outcomes and complications are calculated and guidelines provided (5).

Multiple TQIP programs have been developed and implemented globally (6). To facilitate research, benchmarking and implementation of guidelines trauma patients are generally grouped according to injury or population characteristics (5). Roughly, 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) (7). Overall, brain injury is the most common cause of trauma related death, counting for 58.6 percent of all trauma deaths in Sweden (8). 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 (8). Traumatic brain injury (TBI) is thus highly associated with fatal outcome and is weighing on mortality statistics of both blunt and penetrating patient groups (1,9).

*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) 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 (10,11). 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 (5). TBI is further defined as an AIS severity-score of at least 3 in the head body region, a GCS of maximum 8 at arrival to the emergency room and no other injures with an a severity-score higher than to in any other AIS body region (5).

### 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 (12). Since then, trauma systems have been put into practice in most developed countries, improving mortality and morbidity for severely injured patients (2). 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 review of care are also essential to the trauma system and should be systematically performed at all levels of system (2).

*Trauma centres*

Trauma centres are specialized medical facilities that meet specific criteria established by the ACS. There are five levels of trauma centres, where each level refers to the kind of resources available at the centre and number of patients admitted yearly. Level 1 trauma centres provide the highest level of care and should be equipped for every aspect of injury around the clock. (13) Apart from medical resources such as operating rooms, standby trauma teams, imaging and well-stocked blood banks, level-1 trauma centres should engage in quality assessments and improvement programs for trauma care. (14)

*M&M conferences*

As part of TQIP, all trauma centres should have recurring Mortality and Morbidity (M&M) conferences. At these meetings, a multidisciplinary team of qualified doctors and nurses perform a per review on 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 are assigned by the hospital and should not have participated in the direct care of the patient (15). The aim of the conference is to identify opportunities for improvement and subsequent actions that can be taken to improve future care (16). 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 (17).

### 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 be avoided through optimized action (18). Teixeria et al. and O’Reilly have composed categories of specific OFIs that are recurrent within trauam care: Clinical judgement error, delay in treatment, inappropriate treatment, missed diagnosis and other (19,20). OFIs can be identified regardless of whether patient outcome is in line with what could have been expected or not.

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 ((21). 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 OFIs have been conducted with the aim to identify recurrent errors for specific patient cohorts or trauma facilities. Socioeconomic, cultural and geographic issues, trauma characteristics and healthcare vary between countries and rural/city areas (22,23). 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 (24). 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 (23,25).

These unique characteristics complicate direct translation of results from studies from other economically similar countries. 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 (23). The quality trauma registry at the KUH is the most comprehensive database of serious trauma in Sweden. The database contains information on e.g., OFIs reported form M&M-conferences at the hospital according to American standards, which facilitates comparison between studies of trauma internationally.

Previous studies of the KUH quality database have been focused on OFIs related to preventability of death (8,24). While this gives a broad picture of the most fatal errors, it misses all non-optimal treatment in cases where the patient has lived. It is also difficult to apply clinically with no information provided on what type of patients fall victim to specific OFIs. Trauma servers as an umbrella for several widely different patient groups. 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, each patient group must be evaluated individually for OFIs.

## Aim:

To date, little research has been done on specific OFIs related to specific patient cohorts. The aim of this study is to determine how different clinical trauma cohorts associate with specific OFIs, using data from the quality trauma database at the KUH.

## Material and Methods:

**Study design**

We conducted a registry-based cohort study using data from the trauma registry and the 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 OFIs.

**Setting**

From 2010, The Swedish Trauma society (SweTrau) holds a national registry 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 transfer of patient data to SweTrau due to lack of unified journal systems in Sweden. The coverage was approximately 69.8% as of January 2023 (4).

The KUH is the only facility in Sweden to qualify as a quality level-1 trauma centre according to ACS standards (14,26). 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 (26). All patients treated at the Karolinska University Hospital and who have 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 also reported and registered 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 OFIs. 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 (17).

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 OFIs. 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.

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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. |
|  |

Audit filters, listed in table 1, are specified conditions that all trauma patients are automatically evaluated by. All 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 OFIs are identified in the second round, the patient is brought to a M&M conference for a final assessment of OFIs (17). Results from the conference are stored as specific OFIs in the Karolinska University hospital’s local quality database.

En bild som visar diagram

Automatiskt genererad beskrivning

**Study population**

We studied data of patients registered in both the Swedish trauma registry from SweTrau and the trauma quality data base at the Karolinska University hospital meeting the following criteria:

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

**Variables**

The outcome/ was specific OFIs identified by the M&M-conference at the Karolinska University hospital. The OFIs were further grouped into 5 categories of improvement similar to Teixeria et al (20) and O’Reilly (19), presented in Table 2. Preventable death was included as an OFI for patients passing within 30 days after trauma. The OFI included deaths that assessed as preventable or potentially preventable at conference. Finally, “no OFI”, was included in cases where no OFIs were identified at conference. Only the dominating OFI from conference was counted, each patient was thus only presented once.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 2. Categories of OFI** | | | | | | | |
| Judgement error | Delay | Missed diagnosis | Technical | | Other | No OFI | Preventable |
| Shortage of competence  Wrong level of care  Problem with triage at ED  Error in administration/decis-on 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 OFIs identified at the Karolinska University Hospital M&M conference. | | | | | | | |

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 (10).

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 any of the four patient cohorts, where assigned a fifth category, called “other cohort.” Gender, age, NISS score were used in an adjusted model. All variables were categorical, except forr age which was numerical.

**Data sources/measurement**

Data on AIS score-score, age, NISS-score, gender. GCS-score and intubation was available from the SweTrau Registry. The OFI variable was added from the quality trauma registry at the Karolinska University Hospital, where specific OFIs identified at conference are stored. We used this to create a multilevel variable with different categories of OFI.

**Study size**

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

**Statistics**

All data was processed and analysed in statistical programming software R. Data from SweTrau and the Karolinska University trauma quality registry 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 OFIs 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-score were created.

The models estimate the odd ratio (OR) of each category of 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 obtain the significance of the coefficients in predicting the dependent variable, with the null-hypothesis that there are no association between the evaluated category of OFI and the patient cohort. A p-value of 0.005 (z-value > 1,96) was considered statistically 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. Variables such as ID-number and name were scrambled and anonymised throughout analysis of the real dataset. There were hence no ethical issues in the conduction of this thesis.

# 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 OFIs.

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Automatiskt genererad beskrivning

Table 3. shows demographics of all patient cohorts. BM without TBI was the largest (498) cohort of study. 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 a higher death rate (54.5% and 53.2% respectively) compared with average death of 8.5%. They also had higher average NISS-scores of 40.2 and 49.6 respectively, compared with 30.0 and 33.3 for patients with penetrating and BM without TBI.

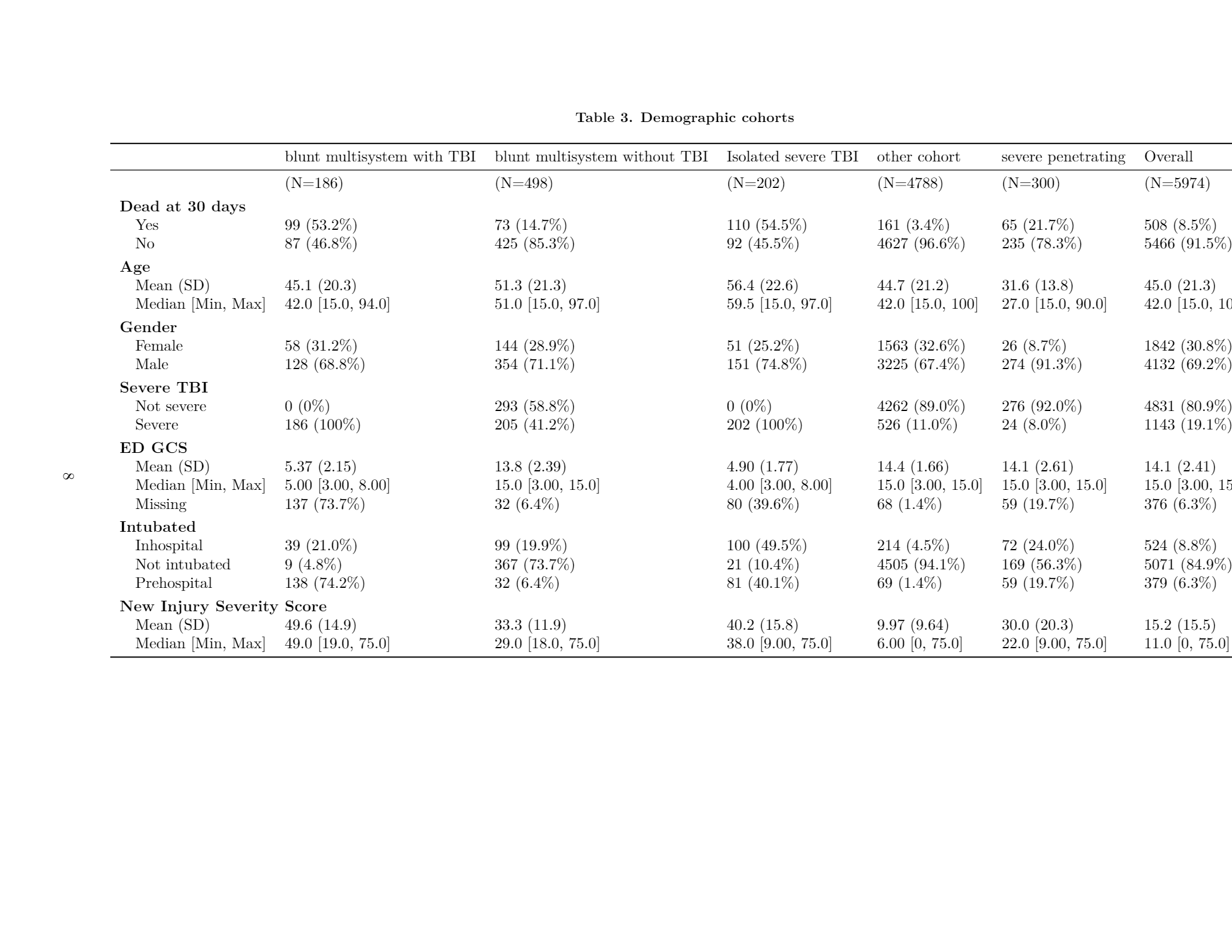
Severe TBI in the table is defined as injury to the head with an AIS >3. Patients with BM injury and severe TBI, who also had a GCS<9 were counted as BM with TBI. Patients with TBI and a GCS >9 was categorised as BM without TBI. This distinction was made to avoid overlap.

Table 2. presents the distribution of cohorts and patients demographics across all seven categories of OFIs. Overall, OFIs were identified in 400 (6.7%) of the patient cases. The most common was error in judgement, 136 (34%). Technical error was least common, detected in 34 (8.5%) of all cases of OFI. Of 508 deaths that occurred within 30 days of trauma, 25 (4.9%) were deemed preventable. Median age for preventable death was 69, which was higher than for other OFIs. Gender distribution was equal across all OFIs.

Table 4.shows the unadjusted odd ratios (OR) for each patient cohort and category of OFI compared with the “other cohort” having no OFI. The cohort that stood out was BM without TBI, which was significantly more likely to have any category of OFI than 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 was also about 4 times more likely to have 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 OFIs such as faults in communication, documentation, or resources (OR 4.33, 95% CI 2.70-6.93, p-value <0.001). The association to preventable death was (OR 6.23, 95% CI 2.29-16.19, p-value <0.001)

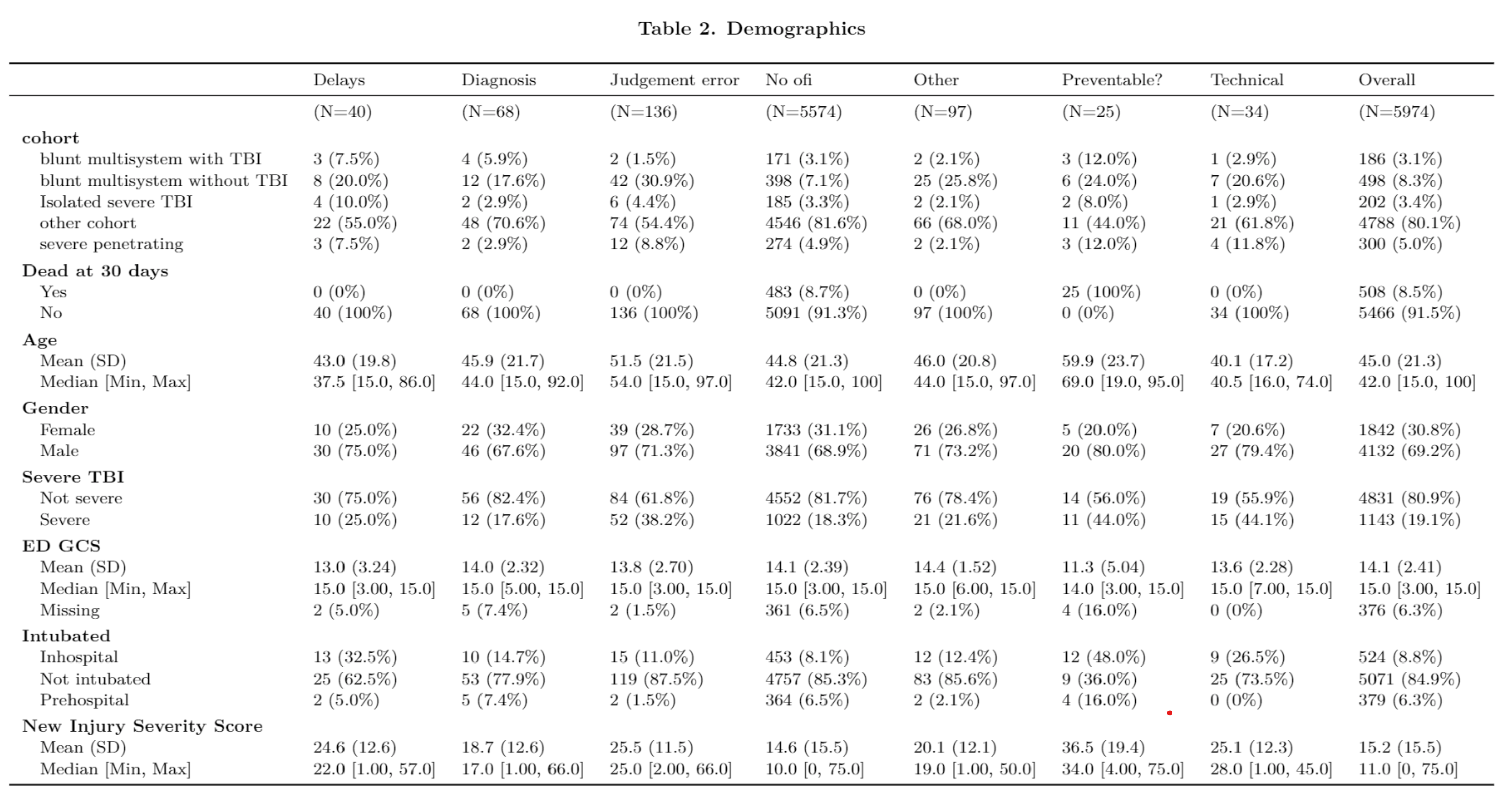
BM with TBI had less significant results. Most substantial was high risk of preventable deaths (OR 7.25, 95% CI 2.00-26.2, p-value 0.003). The cohort was also more likely to have delays in treatment (OR 3.62, 95% CI 1.07-12.2, p-value 0.038). Isolated TBI had significant association to delays in treatment (OR 4.47, 95% CI 1.52-13.1, p-value 0.006). Patients suffering severe penetrating trauma were more likely to have 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-score, statistical association between BM without TBI and delays, missed diagnosis, judgement error, and other OFIs 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 OFIs. This could in part be explained by less data in these groups.



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Automatiskt genererad beskrivning



# Discussion

Trauma includes a diverse set of patient characteristics, both with respect to demographics and mechanism of injury. In this study we assessed association between four trauma cohorts and a set of specific OFIs identified at M&M conferences held at the Karolinska University Hospital.

The most common category of 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. Judgment error was the most common error in both preventable and non-preventable deaths (14.9%) (27). 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 derived to clinical judgement errors where most were related to inadequate patient monitoring. (52.9%) (20). Equally, Matsumoto at el. found that 90.5% of all preventable and possibly preventable deaths, stored in a Level-1 trauma registry at University of California San Diego in 2000-2014, could be derived to errors in judgement (28). Thus, while OFIs related to technical issues seems to be decreasing with advancement in technology, errors related to human decision making prevail (1,19,20,28–30).

BM without TBI was the dominating cohort across all categories of OFIs. It was also the largest cohort in the study. One explanation could be the higher risk of death related to TBI. This is supported by higher mortality within 30 days of trauma for patients with TBI (both isolated and in BM with TBI) as well as higher NISS scores (table 3). Further, if death occurs early after trauma, the patient may have died before errors in care can take place. Trauma mortality is classically described with trimodal distribution; immediate deaths at scene, early deaths due to haemorrhage and late deaths from organ failure (31). A review by Sobrino and Shafi on timing and cause of death after injury showed that brain injury is highly associated with immediate death (32). 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 (27). The high association between BM without TBI and error in judgement is however conspicuous and should be further investigated.

Patients with isolated TBI and MB with TBI were more likely to experience delays in treatment, more specifically long time to operation. Studies of OFIs may be complicated by distinguishment between active and latent errors. Active errors are failures that lead to direct adverse outcomes, whereas latent errors predispose for active errors or adverse outcomes (19). Delays in treatment might thus be an outcome of a latent error in judgement such as failure in decision to take the patient to theatre or lack of adequate competence at site to perform the operation. When O’Reilly studied patients who die from haemorrhage after trauma, OFIs related to decision between surgery, radiology and further investigation were most common (19).

BM patients with TBI were associated to preventable death. Association between isolated TBI and preventable death was however lower. On explanation could be that age serves as an independent predictor of worse outcomes in TBI (33–35). In our study, patients with isolated TBIs were older than other trauma groups, on median 59.5 years (Table 3.). In the US, mortality rates for TBI-patients aged 65 or older were at least twice as hight compared with any younger age group (34,35).

Both patients with isolated TBI and BM with TBI were significantly more likely to be presented with delay in time to operation (Table. 6). This is in accordance with several studies reporting delay in evacuation of intracranial hematoma as the most common the most common cause of preventable death in patients with TBI (36,37). Kim. has further showed that patients who had surgery within 4 hours of arrival to the emergency room had half the likelihood of mortality compared with those who waited longer than 4 hours (38). However, in a literature review of time to surgery for TBI patients, he argues that indication for surgery is a dynamic process as hematomas evolve and that the most critical procedures after arriving to the emergency room is rapid triage, early diagnosis and neurosurgical consultation (36).

Penetrating trauma was the smallest cohort in the study.

**Limitations**

This study was limited to level-1 trauma patients treated at the Karolinska University Hospital. Since the KUH is the only trauma centre in Sweden designed to meet American standards, it diverges from other trauma facilitates regarding competence and equipment. Consequently, results from this study cannot be directly translated to other trauma care providers in the country. Further, the majority of trauma in Sweden is not categorised as level-1 trauma (39), which is the group of focus in this study.

The study has been conducted based on retrospective data, highly dependent on appropriate documentation and continuity in data registration. Before the introduction of audit filters in 2017, patients were randomly selected for reviewed at the KUH. Although the process of selecting patients for evaluation is now formalised, it is still depending on the people involved. Nurses, as well as members of the multidisciplinary team assessing patients for OFIs may be affected by cultural aspects or subjectivity when reviewing peers.

Although 6,310 patients were eligible for study after applying inclusion criteria, only 1,186 were fitted into one of the cohorts of interest. Of these, only 400 were identified with specific OFIs, distributed across 6 categories. Consequently, the number of patients presented under each OFI were scarce, leading to considerable uncertainty. Lastly, only the main category of OFI was registered. Secondary OFIs and latent OFIs could hence not be studied.

**Strengths**

Sweden contrasts from other countries with older population, colder climate, and highly centralised trauma care. This study uses local and recent data with Swedish patients. The KUH is the only level-1 quality trauma centre in Sweden, treating more severely injured patients than any other hospital in Sweden. The quality database held at KUH and used in our study is this unique in coverage and comparability with global data.

Trauma is further a broad term covering all kinds of injuries and patient groups. To assess specific OFIs that can be applied clinically, it is necessary to distinguish between different categories of trauma and patients’ demographics. In this study we analysed four significant patient cohorts for specific OFIs. We also distinguished between suffering BM trauma with and without TBI to avoid overlap between cohorts. The patient cohorts were established based on definitions recognised by the ACS, enabling comparison of data in global context.

**Clinical application**

Our study confirms previous findings of error in judgement as the dominating OFI within trauma care. Many errors have been made avoidable through technological development and clinical practice guidelines (28). When O’Reilly at el. studied OFIs in patients who died from bleeding at the Royal London Hospital from 2006-2010, several interventions were implemented during the study interval. For instance, access to operating theatres and intensive care capacity were improved and a haemorrhage protocol was introduced. Although OFIs related to laboratory services and provision of urgent blood products decreased, issues related to surgeon decision-making persisted (19). Studies have further showed that most errors in decision-making seem to occur early in treatment at the emergency department (19,27,40)

In an anonymous mortality reporting system developed by the ACS for trauma centres participating in TQIP, trauma centres reported preventability of mortality, contributing factors leading to death, as well as type of errors, when they occurred and whether they derived to human failure or faults in the system. The respondents were also given the opportunity to describe their narrative of events and suggest strategies that could help to prevent similar deaths in the future (40,41). Hamad et al. showed that more than half of the strategies were focused on individual improvements (56.0%). Frequent reported strategies included giving direct feedback, education, and review of management guidelines relevant for the patients. Only 11.1% of the cases contained elements of process standardisation or automatization, such as procedural checklists (40).

Standardised trauma protocols in trigae, resuscitation etc have been repeatedly proved to decrease in-hospital mortality (12,42–44) With most errors in judgement occurring in the early, often chaotic phase of trauma, the importance of standardised protocols and decision-making is emphasised.

**Future research**

Further studies of the KUH trauma register should be done to dig deeper into when, how, and where error in judgement occur. The existence of complex OFIs, where series of tightly related events may lead to adverse outcomes.

Although several systematic decision-models, such as ATLS, are implemented and practiced in all ACS qualified trauma centres, they offer some degree of freedom and space for human mistakes. Artificial intelligence such as machine learning is on the verge of revolutionising health care. AI has already proved superior to physicians when it comes to diagnostic imaging.

However, Kelbin and friends showed that .

# Conclusion

Error in judgement is the most common OFI, while technical errors are rare. BM patients without TBI had the highest association to all OFIs compared with other cohorts in the study, partly due to being the largest cohort.

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