Incidence of Opportunities for Improvement

a retrospective cohort study in a Scandinavian level-I trauma centre

1 Background

Trauma, defined as physical injury and the body's associated response[1], is the leading cause of death in patients aged 45 or younger[2]. For every death by trauma, three patients are rendered permanently disabled[3], which significantly amplifies the social and economic impacts of the disease as well as the importance of quality trauma care. The two major mechanisms of injury are blunt trauma, mainly due to falls, traffic accidents and assaults and penetrating trauma, mainly due to stabbing or use of firearms[3].

To ensure high quality trauma care, trauma systems have been implemented throughout the world. Inherent to trauma systems are: (i) centralization of trauma care to specialized trauma centres, (ii) benchmarking of outcomes through trauma registries, and (iii) continuous retrospective assessment of care through mortality and morbidity review board conferences. The multidisciplinary review boards are comprised of representatives from all disciplines involved in trauma care - surgery, neurosurgery, orthopedics, anesthesia and intensive care, nursing, and radiology.

Within trauma epidemiology, much emphasis has been placed in the benchmarking of rates of mortality and morbidity, and rates of death preventability. Mortality and morbidity rates alone may impact care, but it is in conjunction with measures of care quality that they exert their principal relevance. Preventable deaths are thought to constitute such a measure, but studies set out to estimate rates of preventable-, possibly preventable- and non-preventable deaths have reached vastly different results.

There are inherent problems with relying on preventable deaths as a measure for care quality. A death can be considered preventable only if patient care has not been in accordance with treatment guidelines and errors in patient care are related- or indirectly related to the patients death[4]. This introduces a significant bias, as it involves review boards in the labeling of care given by colleagues as ”inappropriate” and related to patient death[5].

To circumvent this, the term ‘opportunities for improvement’ (OFI) have emerged in the trauma literature, representing a coarse dichotomous proxy measure for care quality. It gives a more accurate estimation of sub optimal care rendered and identifies negative trends that may be corrected by the implementation of corrective initiatives. At present, no study has set out to estimate rates of OFI within the Scandinavian trauma population, and as such we lack sound measures of care quality.

1.1 Aim

The aim of this study is to measure the incidence of OFI in care across different cohorts at KUH trauma centre, identify problem areas and estimate temporal incidence trends.

2 Methods

2.1 Study design

A retrospective cohort study using data from the SweTrau and the KUH TCQD was conducted. Patient data were extracted from the Swedish trauma registry (SweTrau) and the KUH trauma care quality database (TCQD). Patients were grouped grouped according to their respective cohorts with a complete case analysis using the programming software R. Data handling and statistical analyses were initially done to a simulated set of data to minimize bias. The semiannual and cumulative incidence of OFI was measured within cohorts. A trend analysis was then conducted by fitting the incidence data into a linear model with a time series component.

2.2 Setting

KUH trauma centre is an American College of Surgeons trauma level-1 centre, which manages 1300 trauma patients each year. Trauma patients are triaged in a pre-hospital setting as a priority one or two by assessing vital physiological parameters, anatomical criteria, and mechanism of injury. The pre-hospital system includes a helicopter emergency medical service and three physician staffed ambulances. The in-hospital system includes a multidisciplinary trauma team comprised of a surgeon, an anesthesiologist, an orthopedic surgeon, a radiologist, a surgical nurse, an assistant surgical nurse, a nurse anesthetist, an emergency medicine nurse, an emergency medicine assistant nurse and a radiology nurse. Consultations with associated specialties are available around the clock. The team has immediate access to radiology, surgery, and intensive care.

There are monthly multidisciplinary trauma mortality and morbidity review boards, which selects patients from the trauma registry using audit filters: systolic blood pressure less than 90; Glasgow coma scale (GCS) less than 9 and not intubated; injury severity score (ISS) more than 15 but not admitted to the intensive care unit; time to acute intervention more than 60 minutes; time to computed tomography more than 30 minutes; and death within 30 days after trauma. The board is comprised of representatives from all disciplines involved in trauma care - surgery, neurosurgery, orthopedics, anesthesia and intensive care, nursing, and radiology. Its purpose is to reach a consensus regarding the presence of OFI and implement appropriate corrective actions (see figure 1). Once the care of a patient is decided to have OFI, the nature of that which can be improved is documented in the KUH TCQD.

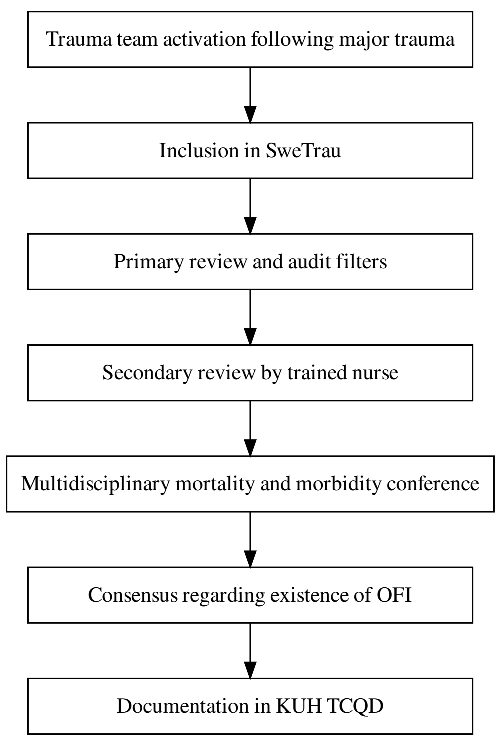

Figure 1: **SweTrau to OFI.** *SweTrau: Swedish Trauma Registry, OFI: opportunities for improvement, KUH TCQD: Karolinska University Hospital's trauma care quality database*

2.3 Participants

2.3.1 Study population

All trauma patients in the KUH TCQD between 2013 and 2021 is included. The KUH TCQD contains all patients in SweTrau, treated for traumatic injuries at KUH. SweTrau includes all patients admitted with trauma team activation to a Swedish trauma centre, as well as patients admitted to a trauma centre without trauma team activation, but retrospectively found to have a new injury severity score (NISS) of greater than 15. Excluded are patients who trigger trauma team activation despite not having suffered a traumatic injury and patients whose solitary injury is chronic subdural hematoma. Moreover, excluded from the study are all patients aged 14 or below and all patients missing data about OFI.

2.3.2 Cohorts

Grouping was conducted pertaining to directives from the ACS TQIP, using the Abbreviated Injury Scale (AIS) grading system, which forms a number of seven digits indicating (i) region of injury, (ii) type of anatomical structure, (iii) specific anatomical structure, (iv) level of injury and (v) severity of injury[6, 7]. Patients were grouped by principal mechanism of injury (blunt, penetrating), post-injury condition (shock, severe traumatic brain injury) and age. The decision to study these cohorts was one taken in accordance with local directives, limitations to the data contained in SweTrau and KUH TCQD, and the time and resources dedicated to this project. Presented below are inclusion and exclusion criteria by cohort.

Cohort inclusion and exclusion criteria

Cohort	Inclusion criteria	Exclusion criteria
Severe blunt multisystem injuries	Blunt injuries with an AIS severity of 3 or greater in at least 2 of the following body regions: head, face, neck, thorax, abdomen, spine, upper, or lower extremity	
Severe penetrating injuries	Penetrating truncal injury with an AIS severity of 3 or greater in the regions of the neck, chest or abdomen	
Severe TBI	Head injury with an AIS severity of 3 or greater and an ED GCS of less than 9	Injuries in separate AIS body region with an AIS severity of 3 or greater
Shock	ED systolic blood pressure less than 90 mm Hg	
Geriatric	Aged 65 years or greater	

AIS: Abbreviated Injury Scale, TBI: traumatic brain injury, ED: emergency department, GCS: Glasgow coma scale, mm Hg: millimeter of mercury

2.4 Variables

Five quantitative variables was used to determine cohort eligibility: age, pre hospital systolic BP, emergency department systolic BP, AIS body region and AIS severity score. Initial cohort data is presented in a descriptive table. Continuous variables are presented as mean, median and interquartile range. Categorical variables are presented as percentages.

2.4.1 Outcome variable

The dichotomous variable OFI (true or false), derived from the variable "problem area" in the KUH TCQD was used as outcome measure. If a multidisciplinary mortality and morbidity review board has reached a consensus regarding the presence of a problem in patient care in at least one of the areas: emergency department triage; tertiary survey; processing; communication; time to computed tomography; time to surgical intervention; level of physician and nursing competency; level of care; neurosurgical intervention; hospital staff routine; resource management; logistics and technology; overall management and documentation, the OFI variable is marked as "true." If a patient case is not discussed at a review board conference, or if the conference is unable to find a significant error in care, the OFI variable is marked false.

2.5 Statistical methods

Data handling and statistical analyses was conducted in the statistical programming software R. Data from SweTrau and KUH TCQD were extracted, matched by patient id and merged. Non-essential columns of variables were removed. Non-informational values were systematically changed to informational ones or removed as per instruction in the SweTrau Manual[8]. Patients were grouped and excluded according to cohort definitions, inclusion criteria and exclusion criteria listed above. Once grouping and exclusion was done satisfactorily, the semiannual and cumulative incidence of OFI was calculated for each cohort and for the study population in its entirety. A linear regression model with a time series component was then applied to the data to estimate the trends of these incidences over time. Excluded patients, as well as their reason for exclusion, were documented in a flowchart. Statistical significance was defined as P<0,05 with a 95% confidence interval.

2.5.1 Bias

The method and algorithm for data analysis were developed on a step-by-step basis using simulated data. It was rigorously tested throughout its development process, until the results using the simulated data set was satisfactory. The algorithm was then reviewed by a trained programmer and statistician. Following approval, the algorithm was not changed, and the data as a result not skewed by the bias of the developer. Selection bias, caused by the inclusion criteria for the KUH TCQD and SweTrau, is possible.

2.6 Ethical considerations

All patient data were collected prior to the start of this study as a part of the Swedish trauma registry, and the KUH TCQD. The study is population based and data is handled restrictively and access given exclusively for the duration of the study. The study is conducted in adherence to good scientific quality. The benefits of this study outweigh by a clear margin, the cost.

2.6.1 Ethical review number:

2021-02541, 2021-03531

3 Results

4 Methods

4.1 Study design

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4.2 Setting

The KUH trauma centre is an ACS level-1 centre, which manages 1300 trauma patients each year. Trauma patients are triaged in a pre-hospital setting as a priority one or two by assessing vital physiological parameters, anatomical criteria, and mechanism of injury. The pre-hospital system includes a helicopter emergency medical service and three physician staffed ambulances. The in-hospital system includes a multidisciplinary trauma team comprised of a surgeon, an anesthesiologist, an orthopedic surgeon, a radiologist, a surgical nurse, an assistant surgical nurse, a nurse anesthetist, an emergency medicine nurse, an emergency medicine assistant nurse and a radiology nurse. Consultations with associated specialities are available around the clock. The team has immediate access to radiology, surgery, and intensive care.

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Table 1: **Cohort inclusion and exclusion criteria**

Cohort	Inclusion criteria	Exclusion criteria
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Severe TBI	Head injury with an AIS severity of 3 or greater and an ED GCS of less than 9	Injuries in separate AIS body region with an AIS severity of 3 or greater
Shock	ED systolic blood pressure less than 90 mm Hg	
Geriatric	Aged 65 years or greater	

Abbreviations: AIS: Abbreviated Injury Scale, TBI: traumatic brain injury, ED: emergency department, GCS: Glasgow coma scale, mm Hg: millimeter of mercury

4.4 Variables

Five quantitative variables was used to determine cohort eligibility: age, pre hospital systolic BP, emergency department systolic BP, AIS body region and AIS severity score. These variables were converted into qualitative variables by division of patients into groups defined by a numerical range (e.g. ages 15-65). Initial cohort data is presented in a descriptive table (See table 3). Continuous variables are presented as mean, median and interquartile range. Categorical variables are presented as percentages.

4.4.1 Outcome variable

The dichotomous variable OFI (true or false), derived from the variable "problem area" in the KUH TCQD was used as outcome measure. If a multidisciplinary mortality and morbidity review board has reached a consensus regarding the presence of a problem in patient care in at least one of the areas: emergency department triage; tertiary survey; processing; communication; time to computed tomography; time to surgical intervention; level of physician and nursing competency; level of care; neurosurgical intervention; hospital staff routine; resource management; logistics and technology; overall management and documentation, the OFI variable was coded as "true." If a patient case is not discussed at a review board conference, or if the conference is unable to find a significant error in care, the OFI variable was coded as "false."

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4.6 Ethical considerations

4.6.1 Autonomy

All patient data were collected prior to the start of this study as a part of the Swedish trauma registry, and the KUH TCQD. No new data had to be collected to perform the analyses. To my knowledge, patients are not asked for permission before inclusion in SweTrau and the KUH TCQD.

4.6.2 Justice

SweTrau and KUH TCQD includes severely injured and deceased patients, but since they are the study group in question, they have to be included. Patients with protected identities are categorically excluded from SweTrau and KUH TCQD. The study is population based and data is handled restrictively and access given exclusively for the duration of the study. Potential benefits following this study outweigh by a clear margin, potential costs.

4.6.3 Beneficence

The study is conducted in adherence to good scientific quality. The findings from this study may influence trauma care at KUH trauma centre; directly impacting mortality and morbidity in the Swedish trauma cohorts. Furthermore, it is important academically, as it fills an important gap of knowledge, demonstrates the value of the TCQD and acts hypothesis generating.

4.6.4 Non-maleficence

The study does not risk harming study participant nor does it damage public confidence in the scientific method. This study does not risk stigmatization of a patient- or societal group. The benefits of this study far outweigh its costs.

4.6.5 Ethical review numbers:

2021-02541, 2021-03531

5 Results

5.1 Participants

Over the pre-specified study period, 12099 patients were included in the the KUH TCQD. 5951 patients were excluded due to the database lacking OFI data for patients with an ED arrival prior to 2017. 5214 (43.1%) patients were aged 15 or greater and had sufficient data regarding OFI (see figure 2). The blunt multisystem cohort was comprised of 463 patients; penetrating of 183 patients; severe TBI of 96 patients; shock of 170 patients and geriatric of 1020 patients. Four categories of data were necessary for grouping: age, emergency department gcs, emergency department systolic blood pressure and dominant injury type (blunt or penetrating). 932 patients lacked data about age, 159 patients lacked data about emergency department gcs and 12 patients lacked data about emergency department blood pressure. No patients lacked data about dominant injury type.

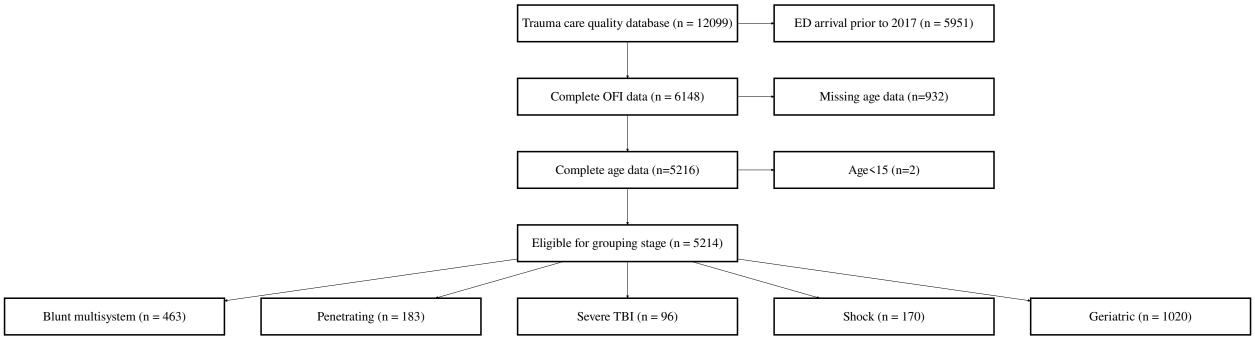

Figure 2: **Exclusion flowchart.** Excluded are all patients patients treated prior to 2017, as they systematically lack data about OFI. *Abbreviations: TBI: traumatic brain injury, ED GCS: emergency department Glasgow coma scale, ED SBP: emergency department systolic blood pressure.*

5.2 Descriptive data

Table 3 presents patient demographics in the trauma cohorts. The cum_inc_blu cohort had the highest percentage of OFI with 17.7% and thecum_inc_all cohort the lowest with 5.8%. The severe TBI cohort had the highest 30-day-mortality with 36.5%, followed by the shock cohort with 34.7%. The study population is male-dominated with 68% men. The two cohorts with the highest average NISS was blunt multisystem (35,3) and severe TBI (34,3).

Table 3: **Cohort demographics**

	Blunt multisystem	**Geriatric**	**Overall**	**Penetrating**	**Severe TBI**	**Shock**
	(N=463)	(N=1020)	(N=5214)	(N=183)	(N=96)	(N=170)
OFI						
No	381 (82.3%)	931 (91.3%)	4913 (94.2%)	172 (94.0%)	83 (86.5%)	151 (88.8%)
Yes	82 (17.7%)	89 (8.7%)	301 (5.8%)	11 (6.0%)	13 (13.5%)	19 (11.2%)
Age (years)						
Mean (SD)	51.3 (21.0)	77.8 (7.94)	45.1 (21.1)	32.8 (15.3)	56.0 (21.5)	49.4 (21.5)
Median [Min, Max]	51.0 [15.0, 97.0]	77.0 [66.0, 98.0]	43.0 [15.0, 98.0]	28.0 [15.0, 90.0]	59.0 [18.0, 89.0]	51.0 [15.0, 93.0]
Sex						
Female	122 (26.3%)	429 (42.1%)	1667 (32.0%)	17 (9.3%)	22 (22.9%)	33 (19.4%)
Male	341 (73.7%)	591 (57.9%)	3547 (68.0%)	166 (90.7%)	74 (77.1%)	137 (80.6%)
ED GCS						
Mean (SD)	13.7 (2.63)	13.8 (2.51)	14.4 (1.79)	14.6 (1.26)	5.49 (1.83)	13.5 (2.92)
Median [Min, Max]	15.0 [3.00, 15.0]	15.0 [3.00, 15.0]	15.0 [3.00, 15.0]	15.0 [3.00, 15.0]	5.00 [3.00, 8.00]	15.0 [3.00, 15.0]
Missing	118 (25.5%)	84 (8.2%)	344 (6.6%)	20 (10.9%)	45 (46.9%)	82 (48.2%)
ED SBP (mmHg)						
Mean (SD)	127 (36.0)	149 (31.0)	137 (26.4)	121 (37.9)	142 (33.0)	62.9 (33.4)
Median [Min, Max]	130 [0, 241]	150 [0, 285]	136 [0, 285]	130 [0, 200]	144 [65.0, 205]	79.0 [0, 90.0]
Missing	17 (3.7%)	22 (2.2%)	83 (1.6%)	5 (2.7%)	1 (1.0%)	11 (6.5%)
NISS						
Mean (SD)	35.3 (13.0)	16.2 (13.0)	12.6 (12.8)	22.8 (13.6)	34.3 (13.4)	31.8 (21.0)
Median [Min, Max]	34.0 [14.0, 75.0]	14.0 [0, 75.0]	9.00 [0, 75.0]	19.0 [9.00, 75.0]	34.0 [9.00, 66.0]	28.0 [1.00, 75.0]
Missing	0 (0%)	0 (0%)	3 (0.1%)	0 (0%)	0 (0%)	0 (0%)
Survival						
Alive	389 (84.0%)	879 (86.2%)	4982 (95.6%)	170 (92.9%)	61 (63.5%)	111 (65.3%)
Dead	74 (16.0%)	141 (13.8%)	227 (4.4%)	12 (6.6%)	35 (36.5%)	59 (34.7%)
Missing	0 (0%)	0 (0%)	5 (0.1%)	1 (0.5%)	0 (0%)	0 (0%)

Abbreviations: SD: standard deviation, ED SBP: emergency department systolic blood pressure, ED GCS: emergency department Glasgow coma scale sum, NISS: new injury severity score, Survival: survival status 30 days post emergency department admission.

5.3 Incidence and problem areas

In the study population, the overall semiannual incidence of OFI ranged from 2.69% to 10.14% (see figure 3). The highest recorded total semiannual incidence was 35.71% in the severe TBI cohort. During the second half of 2017 and the first half of 2018, total overall semiannual incidence is down. The cumulative incidence rate varied across cohorts, as well as temporally within cohorts (see figure 4). The cohort with the largest cumulative incidence was cum_inc_blu (17.71%) and the cohort with the lowest was penetrating (5.77%). The cumulative incidence in the overall trauma population was 5.77%. In the overall trauma population, the four most common problem areas was: resource management (19,8% of total OFI), emergency department triage (16,9%), time to surgery (15%) and injury identification (14,7%), see figure 5.

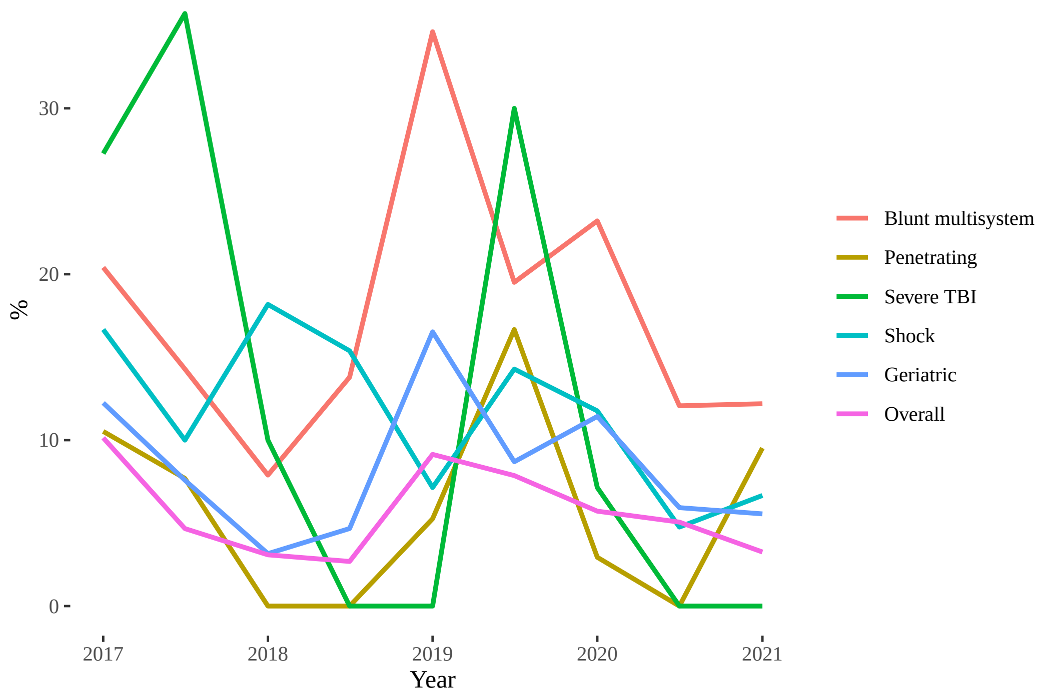

Figure 3: **Semiannual incidence of OFI.** Percentage of cases reviewed with OFI, measured with a six month interval (2017-2021). *Abbreviations: OFI: opportunities for improvement, TBI: traumatic brain injury.*

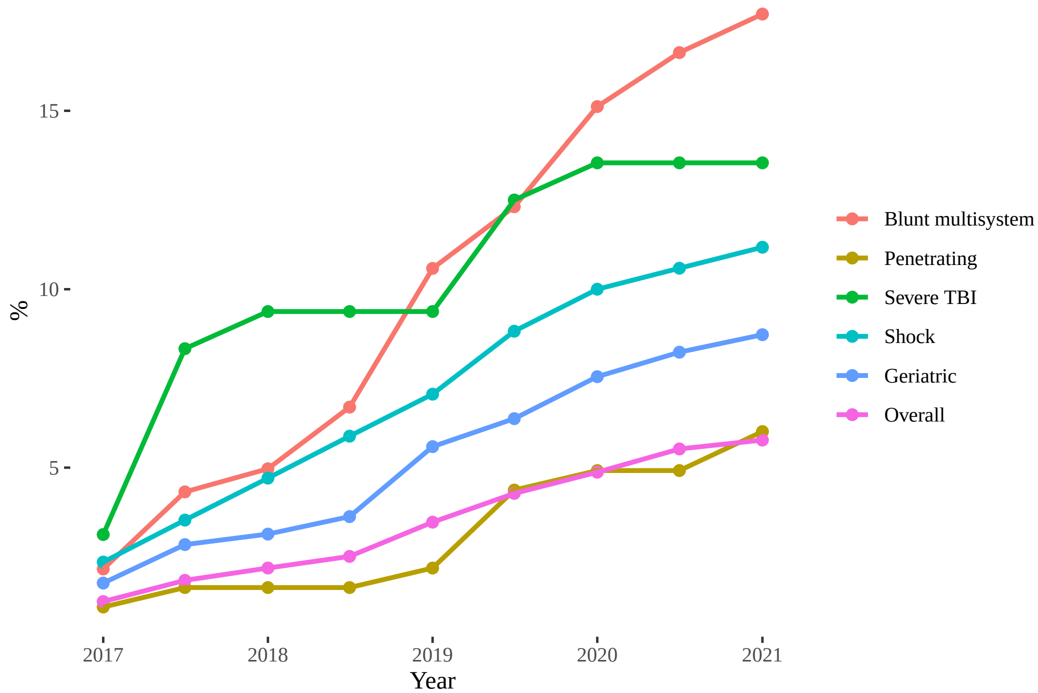

Figure 4: **Cumulative incidence of OFI.** Cumulative percentage of total cohort participants with OFI (2017-2021). *Abbreviations: OFI: opportunities for improvement, TBI: traumatic brain injury.*

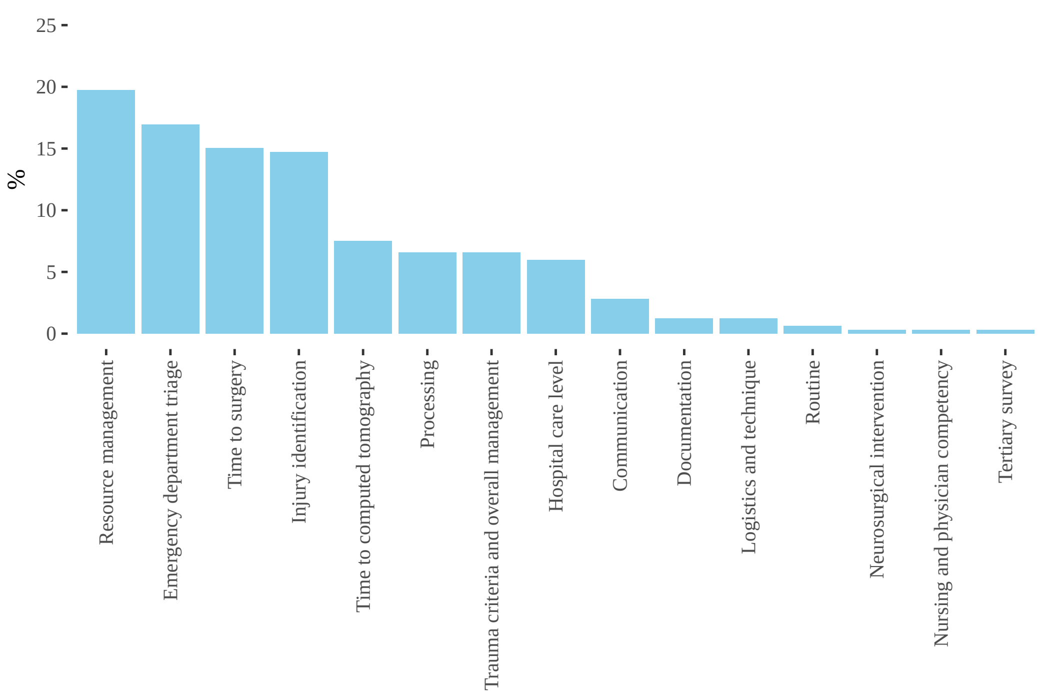

Figure 5: **Identification of specific problem areas.** Percentage of total OFI in the overall trauma population attributable to specific problem areas.

5.4 Trends

Table 4 presents the outcome of a fitted linear model with a time series component. All cohorts had a negative incidence trend estimate. With statistical significance defined as p<0,05, no trends were statistically significant. The steepest trend estimate was that of Severe TBI with -0.017 (CI y-y, p=0,089). Closest to having a statistically significant trend was the shock cohort with p=0,0517.

Table 4: **Temporal incidence trends.** The trend estimate represents the linear models expected decline in OFI incidence every 6 months.

Cohort	**Estimate**	**P value**
Blunt multisystem	-0.0002843	0.9638066
Penetrating	-0.0004157	0.9267983
Severe TBI	-0.0175319	0.0893009
Shock	-0.0063567	0.0517086
Geriatric	-0.0010150	0.7610232
Overall	-0.0014513	0.4890082

Abbreviations: TBI: traumatic brain injury, CI: confidence interval.

6 Discussion

6.1 Key results

The principal aim of this study was to measure the semiannual and cumulative incidence of OFI in the trauma cohorts blunt multisystem, penetrating, severe TBI, shock and geriatric at KUH trauma centre to obtain rough estimates of care quality throughout the trauma population, independent of mortality or morbidity rates. There was sizable variance in the cumulative incidence of OFI across the trauma cohorts; the lowest being in the general trauma population with 5.8%, closely followed by the penetrating cohort with 6%; and the highest being in the blunt multisystem cohort with 17,7%. The highest semiannual incidence of OFI was 35,7% in the severe TBI cohort. Both the penetrating cohort and the severe TBI cohort had a semiannual incidence low of 0%. Between the middle of 2017 and the middle of 2018, overall semiannual incidence of OFI drops. The secondary aims were to identify problem areas in care rendered, and estimate temporal incidence trends. The four most common problem areas in the overall cohort was resource management, emergency department triage, time to surgery and injury identification. All cohorts and the total study population had negative temporal incidence trend estimates suggesting of an overall downtrend, although no p-values were below 0,05.

6.2 Limitations

There are several limitations to this study. First: there was a great deal of overlap across cohorts, and statistical analyses could as a result not be conducted across cohorts. As such, the study is mainly descriptive, with an impaired ability to draw strong conclusions. The method for patients selection to multidisciplinary mortality and morbidity review board meetings relies on audit filters. There is at present no consensus in the trauma literature as to which audit filters are effective: they are chosen, not by careful scientific scrutiny, but by personal preference and well substantiated guesses. Consequently, there is a probability of selection bias as the choice of audit filters influences which patients are discussed. The nature of the high variance within cohorts in temporal incidence of OFI, complicates and weakens the power of the incidence trend analysis. A longer study period would allow for a greater interval, which in turn should result in more patients, less variance and more significant results.

The assignment of OFI is dependent on the review process and temporal incidence of OFI can therefore be affected by factors that impact the frequency of review, e.g. a move to new premises. OFI in care rendered is more likely to be found in patients with outcomes severe enough to draw attention or trigger audit filters, errors in care with less severe outcomes are likely to be overlooked. Therefore, it cannot be claimed that OFI is a true measure for quality of care, but rather measuring the number of severely injured patients, whom have errors in care and severe outcomes. As the average injury severity varies across cohorts, that introduces another source of bias: cohorts with a higher average injury severity should have a higher incidence of OFI. It can be argued, however, that it is for severe patient cases with severe outcomes, that the measure exerts its principal relevance, and that it does not matter much if errors in less severe cases are tossed aside: those are not the errors that matter.

6.3 Interpretation

At KUH trauma centre, the proportional number of serious preventable errors in care is distributed unequally across cohorts. In interpreting the descriptive table of patient characteristics (see table 3), there appears to be a correlation between a high average NISS and the cumulative incidence of OFI. As discussed in the limitations section, that is to be expected. NISS represents injury severity which not only affects the likelihood to be discussed at a multidisciplinary mortality and morbidity conference, but also the complexity of management, which in turn increases the risk of errors in care. On the basis of these results, one might advocate for a larger role of injury severity scores in patient management, but that may be superfluous. A patient with a high injury severity score is obviously already severely injured, hence the scoring, and recommendations arising from the scoring are likely to become circular. A study by Ghorbani et al set out to (i) estimate rate of preventable errors in care and preventable deaths at KUH and (ii) explore the use of two risk scores (TRISS, NORMIT) for predicting preventable deaths[10]. It concluded that both risk scores are poor predictors of preventable deaths. As the scores are normally used for prediction of mortality[11, 12], and the main difference between preventable deaths and deaths in general is the assignment of OFI in care rendered, they should be inaccurate in OFI prediction as well.

The proportional number of serious preventable errors in care in patients in the blunt multisystem cohort, as illustrated by the cumulative incidence of OFI, outnumber those of the other cohorts by a significant margin. In caring for patients of that injury category, nearly one serious error occurs for every five patients admitted to the emergency room. In light of this, one can say with some certainty that there is significant room for improvement in care for patients with severe blunt multisystem injuries at KUH trauma centre. These results are not unambiguous however: in cumulative incidence of OFI there is not a single outlier, but rather a continuum and the results should be interpreted as such. Patients belonging to the penetrating cohort experience fewer errors in care than patients belonging to the geriatric cohort, which in turn experience fewer errors than patients belonging to the shock and severe TBI cohorts and so forth.

The overall cumulative incidence of OFI is 5,8% in our study, but in the study by Ghorbani et al the results of the related measure is around 20%[10]. The greatest methodological difference between the studies lies in their choice of study population: it is comprised solely of patients deceased 30 days following trauma. A significantly higher incidence is therefore to be expected in their study, patients deceased due to trauma are in general more severely injured and require faster administration of generally more complex management. Identical, or close to identical results would have been surprising, a divergence is not.

The notable temporal variance within cohorts in the semiannual incidence graph warrants further explanation. The overall trend of OFI appears at glance to point downwards, which is strengthened by our trend analysis, but several cohorts experience violent shifts in amplitude at several points in time. This would suggest either that the frequency of measurement is too narrow and the population size as a result too small, or that KUH trauma centre experiences radical back-and-forth shifts in patient management. The former appears to be more probable: the severe TBI cohort has the lowest number study participants (n=96), and also coincidentally the most drastic shifts in amplitude. This study would benefit from larger patient cohorts, either by loosening the cohort inclusion criteria, turning it into a multicenter study or expanding the study period.

In order for these results to be practically applicable at KUH trauma centre or any other institution, the isolated fact that errors exist is insufficient. To properly guide quality improvement work, it is imperative to learn which errors are made, which errors are most common and where they occur. This study has set out to partly provide an answer to that as well. The most common reasons for erroneous care at KUH trauma centre are improper resource management, emergency department mistriage, prolonged wait to necessary surgical intervention and diagnosticians failing to identify injuries. These data points should provide a foundation for local quality improvement work and guide corrective initiatives.

The linear trend model predicts negative trends for all cohorts and for the overall study population. Due to the large swings in amplitude, no statistically significant trends have been determined. The trends estimates are small, with confidence intervals spanning both positive and negative values and although they are suggestive of downtrends, the direction (positive or negative) of the trend cannot be accurately established. A statistically significant negative trend in incidence of OFI could go some distance towards validating the effectiveness of trauma quality improvement through multidisciplinary mortality and morbidity conferences.

6.4 Generalisability

The study results are directly applicable to the trauma population at KUH trauma centre as they constitute the study population. The findings might also be valuable for other Scandinavian level-I trauma centres, as they are similar in many aspects, and care for populations with similar demographic characteristics and burden of disease as those cared for at KUH trauma centre. There are a multitude of differences however, one being the use of different audit filters to select patients for review, why the study ought to be replicated at another institution prior to drawing strong conclusions. The external validity pertaining to other Swedish trauma centres is likely limited, as they generally care for less severe patients and differ in their organisational structure.

6.4.1 Equity

Trauma is primarily a male disease, something which is evident in this study as 68% of participants are members of the male sex (See table 3). As with any discipline, practice makes perfect: there is a volume outcome relationship in trauma care. Consequently, one could be tempted to believe that care received by the female trauma population is inferior to that of the male trauma population. However, several large, multicenter studies investigating the relationship between sex and outcome in trauma care have not found a positive correlation between female sex and increased mortality or morbidity[13–16]. To the contrary, a large multicenter study from the Netherlands found a negative correlation between female sex and increased mortality[15]. This study has not stratified by sex for the statistical analyses, and is as such unable to speak towards the relationship between sex and OFI at KUH trauma centre. The uneven distribution of female trauma patients does not affect the external validity, as the distribution matches that in the Swedish trauma population.

There appears to be a correlation between age and OFI: the geriatric cohort has a considerably higher cumulative incidence of OFI than the overall cohort. Injury panorama and injury response in the elderly, as well as proper diagnosing and management, differ from that of the average adult[17]. A discrepancy in the number of preventable errors in care between the geriatric and the overall trauma population may therefore be unsurprising, but is nonetheless worrying. Some studies have argued that the combination of old age and traumatic injury should be introduced as a definitive criteria for trauma team activation[17]. Improvement oriented studies after the same fashion may offer a way forward towards better caring for the elderly.

6.5 Future studies

Future studies should seek to validate or disqualify the audit filters used at KUH trauma centre. The value of audit filters is as a predictor for erroneous care rendered: as a predictor for OFI. A study conducting a large multiple logistic regression analysis to establish factors associated, and independently associated with OFI would therefore be of great value. To improve and solidify audit filters is to further automate and streamline patient selection for quality improvement work, which in turn reduces resources and efforts invested and ensures a well functioning review process. Additionally, it would render the concept of trauma quality improvement more easily applicable to smaller trauma institutions, although the effectiveness of a specified set of audit filters at KUH can never ensure their effectiveness elsewhere.

Moreover, more studies should seek to estimate the incidence of OFI within different parts of the trauma population at KUH. They should have a longer study period with a greater number of participants, a greater number of cohorts and include variables such as sex and age in the analyses. Moreover, they should seek to stratify the in-group incidence of OFI into the proportion of their respective problem areas, to further guide quality improvement work.

6.6 Conclusion

The cumulative incidence of OFI was disproportionately distributed among the trauma cohorts. Patients suffering from severe blunt multisystem injuries receive inadequate care at KUH and efforts need to be undertaken to improve the quality of care offered to patients in that category. The four main areas of improvement in the study population are improper resource management, emergency department mistriage, prolonged wait to necessary surgical intervention and diagnosticians failing to identify injuries, and these should provide the primary targets for corrective initiatives. The findings of this study are primarily applicable to the KUH trauma centre, and may come to influence future quality improvement work at the hospital. Continuous quality improvement is a pillar of every modern trauma institution. At KUH in Solna, Sweden, a lot has already been achieved in terms of quality improvement. These findings however, indicate that we still have some way to go.

6.7 Contributions

This project has a counterpart, conducted by student Hussein Albaaj, which is also supervised by Martin Gerdin Wärnberg and Jonatan Attergrim. His projects contain similar elements to mine, why there has been some cooperation. The cooperation has been exclusively focused on the programming aspects of the projects, mainly by sharing chunks of code applicable to data handling and statistical analyses. There has been no cooperation in the writing of the paper, nor in the more advanced aspects of programming, as our aims diverge to the degree that it would not have been useful.

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