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

**A registry based study**

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# Abstract

Evaluation and quality assessment is essential in modern trauma systems implemented in most modern countries. Several studies have demonstrated that the implementation of protocols to decrease human errors and system dysfunctions in trauma care are able to improve quality of care and decrease preventable trauma death (1,2). All level 1 trauma centres should have M&M conferences as an integrated part of trauam care, where relevant disciplines meet regularly to discuss and review patient cases for OFIs. In Sweden, the Karolinska University Hospital is the only facility to qualify as a trauma-1 centre. In this study we merged data from the national trauma registry SweTrau and the quality database at Karolinska to study OFIs for four non-overlapping trauma cohorts.

# Abbreviations

# 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. It kills around 4.4 million people around the globe (3) and in Sweden, almost 10,000 people suffer from severe trauma yearly. (4) Trauma is generally 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 injury of the brain is thus highly associated with fatal outcome (1,7) and is weighing on mortality statistics of both cohorts. Traumatic brain injuries (TBI) are therefore often separated and studied as a category of its on.

*AIS score*

The abbreviated injury scale (AIS) is a 6-point scale scoring system ranking the severity of injury for five anatomic regions, and has been implemented as standard categorization of injury for trauma patients internationally (8,9). The American College of Surgeons (ASC) Trauma quality improvement program (TQIP) has further used the AIS-system to create definitions for patient cohorts (blunt, penetrating, TBI)(10). This facilitates comparability and thereby studies of trauma patient data internationally.

### 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 modern 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 center, (iii) post-hospital care and (iv) injury prevention. (2).

*Trauma centres*

Trauma centres, essential to the trauma system, 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. (12) Apart from medical resources such as operating rooms, standby trauma teams, advanced x-rays and well-stocked blood banks, level-1 trauma centres should engage in quality assessments and improvement programs for trauma care. (13)

*M&M conferences*

Mortality and Morbidity (M&M) conferences are recurring meetings at trauma centres. At conference, a multidisciplinary team of qualified doctors and nurses evaluate selected patient cases to establish whether death could have been prevented and/or any other errors in the care have occurred. The aim of the conference is to identify opportunities for improvement and subsequent actions that can be taken to improve future care (14). The conduction of 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 (15).

### 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 (16). OFIs can thus be identified in all care processes 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 sorted into 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 ((17). 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 (19,20). 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 (21). 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 trauma-1 patients (20,22).

As mentioned, the ACS have sorted trauma injuries into patient cohorts according to the AIS system. To date, Swedish registry studies on OFIs have mainly looked at three cohorts: blunt multisystem/single trauma, penetrating trauma and TBI (6,21) However, brain injury being the most common cause of all traumatic death, creates an overlap between TBI and multisystem trauma cohorts. In this study, the blunt multisystem cohort is therefore analysed both with and without TBI to avoid bias and to establish better understanding for preventability of death and distinguish between errors in care when brain injury is not the main area of concern.

In addition, previous studies of the trauma registry held by the Karolinska have used OFI as a composite measure for all potential lapses leading to un-optimal care. Although this approach offers insight to whether opportunities for improvement exist, it is insufficient in providing health care workers with guidance to concrete actions that may improve care of trauma patients.

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## Aim:

This study hence aims at identifying association between OFIs for non-overlapping cohorts.

## Material and Methods:

**Study design**

We conducted a registry-based cohort study on a merged dataset linking data from the Swedish trauma registry SweTrau and the trauma care quality database at the Karolinska University Hospital. The combined data were further assessed through a multinominal multivariable logistic regression model to assess how clinical cohorts associate with 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 a trauma alarm or generated injuries with a new injury severity score (NISS) above 15, or have been transferred to hospital within 7 days of trauam and have a NISS score higher than 15. Patients where subdural hematoma is the only traumatic injury and cases that have triggered a trauma alarm without underlying trauma are excluded. There are no automatic transfer of patients to SweTrau due to lack of unified journal systems in Sweden. The coverage was approximately 69.8% January 2023 (4).

The Karolinska University hospital is the only facility in Sweden to qualify as a quality level-1 trauma centre according to ACS standards (13,23). 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 standards (23).

As part of level-1 criteria, multidisciplinary M&M conferences are held regularly to evaluate treatment of patients and identify 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 (15).

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, which serve as a foundation for enhancement of care. 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 formalized with the introduction of audit filters.

Audit filters, listed below, 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 glitches in care. Patients selected by the first nurse are then reviewed again 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. (15). Results from the conference are stored in the Karolinska University hospital’s local quality care database.

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Automatiskt genererad beskrivning

**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.

**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/dependent variable was opportunities for improvements (OFI) detected by the M&M teams at the Karolinska University hospital. The OFIs were further grouped into 5 categories of improvement similar to Teixeria et al (18) and O’Reilly (24), presented in table X. Preventable death was included as a category for patients passing within 30 days after trauma. The variable held true for deaths considered either preventable or potentially preventable at conference. Finally, “no OFI”, was included in cases where no OFIs were identified at conference.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **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 |
| 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; a seven-digit number were each position offers 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 the specific anatomic structure (e.g. femur). The next two-digits indicate the level of injury and the final, single number, the severity. The inclusion criteria for the four cohorts in this study are listed below (8).

1. *Blunt multisystem trauma*: Blunt trauma with AIS ≥ 3 in at least two of the following AIS body regions: head, face, neck, thorax, abdomen, spine, or upper and lower extremities.
2. *Isolated severe TBI*: Injury isolated to the area of the brain with an AIS ≥ 3 and:
   1. A pre-or in hospital GCS of <9

or

* 1. Pre – or in hospital intubation

1. *Blunt multisystem trauma without TBI*: Blunt trauma with AIS ≥ 3 in at least two of the following AIS body regions: head, face, neck, thorax, abdomen, spine, or upper and lower extremities. All patients that had injury to the head with an AIS ≥ 3 **AND** a GCS<9 where excluded.
2. *Penetrating trauma*:At least one AIS ≥ 3 injury in any of the following AIS body regions: neck, thorax, and abdomen.

All patients that did not qualify into any of the four patient cohorts, where stored into a fifth category, “other cohort.” Gender, age, NISS score were used in an adjusted model. All variables were categorical, except för age which was numerical.

**Data sources/measurement**

Data on AIS score-score, age, NISS-score, gender. GCS-score and intubation was provided from the SweTrau Registry. The OFI variable was added from the quality trauma registry at the Karolinska University Hospital. The variable is stores as a binary yes/no. Information on what area of improvement the OFI derives from is also provided. We used this to create a multilevel variable with different categories of OFI.

**Study size**

Of […] patients in the SweTrau trauma registry 2017-2022, […] had also been treated and assessed for OFIs at the Karolinska University hospital in accordance with standards for M&M conferences implemented at the hospital in 2017. All patients younger than 15 were excluded, as well as patients with missing data in variables relevant to assess cohort inclusion criteria, leaving 5,974 patients eligible for study. Table.1 shows numbers and distribution of missing values leading to exclusion.

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Automatiskt genererad beskrivning

**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. 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 an model adjusted for age, gender and NISS-score were created.

The models estimate the probability of each category of OFI for each patient cohort. “No OFI” was set as reference for the dependent variable and “Other cohort” for the independent variables. 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**

Studies of the trauma quality database at the Karolinska University Hospital has been ethically approved by… The SweTrau is a public registry. 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

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%. 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. Only the dominating OFI from conference was counted, each patient is thus only presented once. Overall, OFIs were identified in 400 (6.7%) of the patient cases. The most common was error in judgement, 136 (34%). The category included problems at triage, shortage of competence and error in administration. 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. One possible explanation is higher overall death among older patients. Gender distribution was equal across all OFIs.

Table 4 **s**hows the odd ratios (OR) for each patient cohort and category of OFI compared with “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.) and an OR of 6.48. The cohort was also about 4 times more likely to have delays, technical issues and other OFIs such as faults in communication, documentation, or resources. The risk of preventable death was 4,53.

BM with TBI had less significant results. Most substantial was high risk of preventable deaths (7.25). The cohort was also more likely to have delays in treatment. Isolated TBI had significant results of higher risk for delays in treatment (4.47). Patients suffering severe penetrating trauma were more likely to have technical errors (3.16), error in judgement (2.69) and preventable death (4.53).

After adjusting for age, gender and NISS-score, results for BM without TBI remained significant. 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 on a 0.05 level was however lost for all other cohorts. This could in part be explained by smaller data in these groups.

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# Discussion

1-2 sentences that recap the research question

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%) (25). Similar results have also been reached in the US. When Teixera et al. studied preventable deaths in a level 1 trauma centre in the US in 1998-2005, 21.6% could be derived to clinical judgement errors where most were related to inadequate patient monitoring. (52.9%) (18). Equally, Matsumoto at el. studied trauma deaths using Level 1 trauma registry at University of California San Diego with data from 2000-2014. Errors in judgement accounted for 90.5% of all errors detected in preventable of possibly preventable deaths (26). Thus, while OFIs related to technical issues seems to be decreasing with advancement in technology, errors related to human decision making prevails (1,18,24,26–28).

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 death within 30 days of trauma for patients with TBI (table 3). Further, if death occurs early after trauma, the patient may have passed before other errors in care can take place. Injury mortality is classically described with trimodal distribution; immediate deaths at scene, early deaths due to haemorrhage and late deaths from organ failure (29). A review on timing and cause of death after injury showed that brain injury is highly associated to immediate death (30). However, when adjusting for death on arrival, Ghorbani and Strömmer found that TBI related death increased and that most TBI deaths occur late (25).

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 (24). 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 (24).

Discuss preventability [Preventable or Potentially Preventable Mortality at a Mature... : Journal of Trauma and Acute Care Surgery (lww.com)](https://journals.lww.com/jtrauma/Abstract/2007/12000/Preventable_or_Potentially_Preventable_Mortality.21.aspx). Compare outcomes with ours. Our ofis are not directly associated to death.

* The most common cause of death was bleeding, followed by multiorgan dysfunction syndrome
* Most common errors (ofi) contributing to death :
  + delay in treatment (52,9%), failing to activate trauma team, resulting in bleeding to death
  + Clincal judgement error (21,6%) – inadequate monitoring of the patients – long time to DT – missing hemorrage or intra-cranial bleedning -leading to herniation
  + Missed diagnosis (11,8%) – missing injuries on CT or during laparotomy
  + Technical error (7,8%) – intracranial bleeding of coagulopathic patient during ICP, surgical errors
* Also looked at timing of preventable deaths
  + Classic distribution within the first 1-6 hours after injury
  + In this study: most preventable deaths occurred later, but due to early errors. Most preventable deaths occurred within 7 days, 1/3 later
* Early deaths are considered preventable – could be prevented if injuries are identified and treated properly [Preventable trauma deaths: from panel review to population based-studies](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1475565/)

[Preventable trauma deaths: from panel review to population based-studies](https://kise-my.sharepoint.com/personal/maja_martos_stud_ki_se/Documents/Projektarbete%20perinatologi_2.docx)

Identified OFIs for patients dying from bleeding. Hemorrhage second most common cause of death, leading cause of preventable death. Trauma registry – similar M&M process

* Active and latent failures – focused mainly on active. Latent discussed and registered in absence of active failures
* Patients dying from CNS injury where bleeding contributed to the process were included
* OFIs:

1. Missed, delayed or inappropriate surgery – most common problem with surgical decision making – most critical decision is between immidate intervention and further investigation
2. Missed, delayed or inappropriate radiology
3. Missed or delayed diagnosis
4. Technical errors rare , more common related to interpretation of radiology
   1. 73,3% of ofis were capable of affecting patient outcome
      1. 18% of these lack of technical skill
      2. 57% decision-making
      3. 37% beyond control of clinicans

Interventions during the study:

* Infrastructure, improved theaters
* 24h physician led prehostpial care
* Training of suregons, consultant surgeon input
* massive hemorrhage protocol: prehospital notification, rapid access to blood in ED, focus on early intervention
* 1/4 penetrating, CNS 55,6%, blunt trauma 75,5%
* Most errors occurred in the emergency room, and most deaths
* High mortality related to TBI
* How do the results relate to current research
  + Different patient cohorts

[Analysis of preventable deaths and errors in trauma care in a Scandinavian trauma level-I centre](https://onlinelibrary.wiley.com/doi/abs/10.1111/aas.13151)

Study performed on KUH dataset

Error preventable death:

* Clinical judgement 53,8% ( 43,2%): Inappropriate treatment 38,4% (31,3%)
* Delay in treatment 7,7% (10,4%)
* Missed diagnosis 15,4% (19,4%)
* Technical errors 0%
* Other 15,4% (22,5%)

**Strengths**

Evaluation decrease mortality

TBI most common cause of death, we have separated this category

**limitations**

* OFIs are dependent on competence of people in M&M team – different models for agreement between panelists [Preventable trauma deaths: from panel review to population based-studies](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1475565/)
* Research is limited to trauma-1 patients, severely injured patients
* Retrospective study dependent on proper documentation
* Few patients qualify into patient cohorts, small number of patient with

**Further research**

[Opportunities for improvement in the management of patients who die from haemorrhage after trauma - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/23483534/)

Problems with judgement are more common than those of skill. Death from traumatic haemorrhage is associated with identifiable, remediable failures in care. The implementation of a systematic trauma quality improvement system was associated with a fall in the mortality rate among patients presenting in shock.

[Multiorgan Dysfunction After Severe Traumatic Brain Injury: Epidemiology, Mechanisms, and Clinical Management - ScienceDirect (ki.se)](https://www-sciencedirect-com.proxy.kib.ki.se/science/article/pii/S0012369221000465)

Multisystem with traumatic brain injury

Extracranial organ dysfunction after severe TBI has traditionally been studied on an individual organ system basis; however, data suggest that multisystem organ dysfunction after TBI is common and likely share similar mechanistic and pathophysiologic features with single organ system dysfunction

Could it be that multisystem with tbi die because of tbi, therefore less ofi and preventability?

[Unexpected contribution of moderate traumatic brain injury to death after major trauma - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/10568718/) - TBI is an independent predictor of mortality in multisystem trauma

[Risk-adjusted mortality in severely injured adult trauma patients in Sweden - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/35383831/)

[Simultaneous multisystem surgery: An important capability for the civilian trauma hospital - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/27359088/)

[Timing of surgery after multisystem injury with traumatic brain injury: effect on neuropsychological and functional outcome - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/17495732/)

[Emergency department management of traumatic brain injuries: A resource tiered review - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/32923328/)

[*The catecholamine response to multisystem trauma - PubMed (ki.se)*](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/1642533/)

[Risk Factors and Neurological Outcomes Associated With Circulatory Shock After Moderate-Severe Traumatic Brain Injury: A TRACK-TBI Study - PubMed (ki.se)](https://pubmed-ncbi-nlm-nih-gov.proxy.kib.ki.se/35593705/)

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