Major blunt trauma causes increased mortality up to 12 years: Long-term survival in 3 557 patients compared to 35 502 control persons

Joonas Kuorikoski M.D.*; Tuomas Brinck M.D., PhD #; Kirsi Willa M.S.§; Mikko Heinänen M.D. #; Lauri Handolin M.D., PhD #, Tim Söderlund M.D., PhD #

* Surgical unit, Central Hospital of Central Finland, Jyväskylä, Finland
\# Trauma Unit, HUH Musculoskeletal and Plastic Surgery, Helsinki University Hospital, Helsinki, Finland
§ Helsinki University Hospital, Helsinki, Finland

E-Mail:joonas.kuorikoski@fimnet.fi, tuomas.brinck@hus.fi, kirsi.willa@hus.fi, mikko.heinanen@hus.fi, tim.soderlund@helsinki.fi, lauri.handolin@hus.fi

Corresponding author:
Tim Söderlund
email: tim.soderlund@helsinki.fi
telephone: +358505607539
Address: Töölö Hospital, P.O. Box 266, 00029 HUS, Helsinki, Finland

Keywords: Trauma, long-term, blunt, mortality, outcome

Major blunt trauma causes increased mortality up to 12 years: Long-term survival in 3 557 patients compared to 35 502 control persons

Keywords: Trauma, long-term, blunt, mortality, outcome

ABSTRACT

Background

Trauma registries usually report 30-day or in-hospital mortality as an outcome measure. However, some studies criticize this measure as inadequate; the impact of a major trauma could last longer than 1 month after the injury. We studied the long-term mortality of patients who sustained a major trauma.

Methods

The Helsinki University Hospital's trauma registry was used for patient identification from 2006 to 2015 (New Injury Severity Score ≥ 16 and blunt mechanism of injury). For each trauma registry patient, 10 control persons matched by age, sex, and county of residency were obtained from the Population Register Center of Finland. Cause of death information was obtained from Statistics Finland.

Results

We included 3 557 trauma registry patients and 35 502 control persons. Follow-up ranged from 1 year 7 months to 11 years 7 months.

The 1-year mortality was 11 times higher in the trauma-patient group (22% vs. 2%). The long-term (approximately 12 years) mortality after the injury was 2.6 times higher in the trauma-patient group (46% vs. 18%). For patients surviving at least 1 year post-trauma, the mortality at 12 years was 2.2 times higher than in the control group (31% vs. 14 %). The cause of death was a disease in 73.3% of the trauma patients and 93.6% of the controls. Accidents were more often a cause of death in the patient population than in the control population (21.2% vs. 4.1%). Suicide was the cause of death in 3.0% of patients and 1.1% in controls. Several factors associated with increased mortality were identified.

Conclusions

Major trauma patients had significantly higher long-term mortality compared to controls. To the best of our knowledge, this is the first study on this subject with a follow up of this duration with patients this severely injured and a cohort this large.

Introduction

Early mortality of major trauma patients is widely studied. Traumatic brain injury (TBI) and exsanguination account for the majority of early trauma deaths, followed by sepsis and multiple organ failure (MOF) [1]. As recommended in the Utstein criteria, trauma registries usually define the outcome of trauma patients by 30-day or in-hospital mortality as a fixed endpoint [2,3].

However, 30-day or in-hospital mortality has been criticized as an inadequate outcome measure for trauma patients [4-7]. The impact of a major trauma on mortality lasts longer than 1 month after the injury and trauma patients have higher cumulative mortality after hospitalization compared to the general population [4-6,8,9]. Despite large cohort sizes, studies addressing mortality after hospitalization usually include patients with a mean Injury Severity Score (ISS) <12. Although no specific ISS categorizes a patient as a major trauma patient, ISS >15 has been widely used for this definition [10,11]. Thus, most previous studies do not focus on major trauma patients only but present a very heterogeneous mix of trauma patients.

Previous studies have shown increased long-term mortality of trauma patients. The overall mortality of trauma patients was noted to be high in a rather brief follow up of 36 months [9]. A small study (n=103) revealed long-term mortality of trauma patients at 20 years was approximately three times higher than that of the general population (15% vs 5%) [12]. Laupland et al. also observed that the effect of major trauma is long lasting [7]. The factors that predict hospital mortality and delayed mortality after discharge in trauma patients differ considerably between studies [5,13].

This study focused on long-term mortality of major trauma patients in a large trauma population. We aimed to determine the long-term excess mortality after a major blunt trauma and to study possible factors associated with mortality.

Methods

Trauma system in Helsinki, Finland

All major trauma patients receive initial treatment in public hospitals. Privately funded hospitals are not capable of treating major trauma in Finland. Full insurance coverage in Finland is mandatory for occupational accidents and traffic accidents. Insurance coverage does not influence the initial care of a major trauma patient in Finland; all these patients are treated in public hospitals regardless of insurance coverage.

In southern Finland, the Helsinki University Hospital (HUH) Trauma Unit is responsible for the treatment of adult patients with major blunt trauma and, until 1.9.2015, pediatric major trauma patients with suspected head injury were also treated in the HUH Trauma Unit. The catchment area of HUH during the study period was approximately 1.8 million inhabitants (one third of the Finnish population).

Patient identification

The HUH trauma registry (HTR) was used for patient identification from 1.1.2006 to 31.12.2015. The HTR includes only patients treated at the HUH Trauma Unit. Penetrating trunk injuries and children <16 years are not included in the registry as they are treated at another unit of the same university hospital. However, pediatric major trauma patients with head injury or suspected head injury were included in the HTR until 1.9.2015. The inclusion criteria for the HTR were ISS ≥16 in 2006 to 2011 and NISS ≥16 from 2012 onwards. In this study, we included patients with NISS ≥16 and blunt injury mechanism. In case of several admissions to the HTR for one patient during the study period, only the first admission was included.

For each trauma registry patient included in this study, we obtained 10 control persons from national registries by the Population Register Center of Finland. Control persons were matched by age (±6 months), sex, and county of residency on the day of the accident. The data from the Population Register Center was collected on 1.8.2017 and represents the situation on 31.7.2017, which was the end of our follow-up. Thus, the follow-up ranged from 1 year and 7 months to 11 years and 7 months. The follow up concluded at death, end of follow-up, or on the date the person moved to another country.

The socioeconomic status of patients and control persons was obtained from Statistics Finland. Socioeconomic status is registered annually, thus the year of the accident was used for trauma registry patients and control persons. Socioeconomic status was divided into the following eight categories: self-employed persons, upper-level employees, lower-level employees, manual workers, students, pensioners, long-term unemployed, and unknown. The cause of death information was obtained from Statistics Finland, except for patients who died in 2017. Thus, the death certificate data was not available from the last 7 months of our follow-up period. The death certificate data included classification of death (disease, work-related disease, accident, medical treatment, suicide, homicide, war, and unknown) and cause of death by ICD-10 code. Pre-existing co-morbidity of the patient cohort was assessed by the American Society of Anesthesiology (ASA) grading [14]. The patients injured at work or in traffic accidents were considered to have full insurance coverage as these insurances are mandatory and they cover all healthcare costs and provide compensation for the loss income. Voluntary insurances have certain limits in their coverage and do not compensate for the loss of income.

SPSS Version 25 was used for statistical analyses. Pearson chi-square was used in comparison between categorical variables and Mann-Whitney U for comparison between continuous variables.

$p<0.05$ was considered statistically significant. Log-rank test (Mantel-Cox) was used to compare the statistical difference between survival of patient and control cohorts.

Kaplan-Meier survival analysis was used to compare long-term mortality between trauma registry patients and control persons. Cox regression analysis was performed for trauma registry patients with at least 1 year of post-trauma survival. Categorical factors included in the analysis were socioeconomic status (eight categories), gender (M/F), ASA (ASA1, ASA2, ASA3-4, and unknown), full insurance coverage (yes/no), suicide attempt (yes/no), first measured (at scene of accident or at hospital admission) Glasgow coma scale (GCS 3-15), discharge destination from HUH Trauma Unit (home, intensive care unit [ICU], or high dependency unit [HDU], other, rehabilitation, ward, and unknown), and severity of head injury (head AIS, 0, 1-2, 3-4, and 5-6). Continuous factors included age (years), length of stay in intensive care unit (ICU, days), days ventilated, and new injury severity score (NISS, range 16-75).

For this register study, no ethics committee approval was needed according to Finnish law. The HUH scientific review board and the review boards of the Population Register Center and the Statistics Finland approved the study.

Results

Follow up

The follow up (FU) varied from 1 year and 7 months to 11 years and 7 months. Median FU was 5.0 years.

Demographics

We included 3 557 trauma registry patients and 35 502 control persons. We excluded 35 trauma registry patients with permanent residency outside Finland on the day of the accident. We also excluded 7 patients who had denied the use of their data for research. Only 15 patients could not be matched with 10 control persons; these patients had on average 5.5 control persons. The register data retrieval is presented in Figure 1.

Demographics of the patient population are shown in Table 1. Traumatic brain injury was present in 71.9% (n=2 560) of the patients. Head AIS was 1-2 in 8.5% (n=301), 3-4 in 29.7% (n=1 056), and 5-6 in 33.8% (n=1 203) of the patients. A total of 2 806 (78.9%) patients were admitted to ICU and 1 965 patients (55.2%) were mechanically ventilated. The mean ICU stay was 5.6 ± 7.4 days and the mean duration of mechanical ventilation was 3.4 ± 5.7 days. Altogether, 30.9% of patients (n=1 098) had full insurance coverage. The majority of the patients (51.6%, n=1 835) were discharged to a ward in other hospitals (in Finland most patients are transferred to a step-down hospital after treatment as soon as University Hospital resources are no longer needed). The next most common discharge destinations were home (18.4%, n=656) and ICU or HDU in another hospital (13.4%, n=475). The remaining patients (3.9%, n=139) were discharged to rehabilitation or other institutions. The in-hospital mortality was 12.7% (n=452) during the initial hospital period. The cause of injury was suicide attempt in 5.1% (n=183) cases.

Long-term survival analysis (Kaplan-Meier)

The Kaplan-Meier survival analysis for patients (n=3 557) and controls (n=35 502) is shown in Figure 2. The effect of early deaths is seen as a rapid decline in survival in the patient population. After the early deaths, the slope of the survival curve is steeper throughout the follow up in trauma registry cohort patients. The slope of the survival curve in controls is rather constant throughout the follow-up period. The difference between survival of patients and controls was statistically significant (log rank $p < 0.001$).

A total of 452 (12.7%) patients died during the initial hospital stay and 783 patients (22%) were deceased at 1 year. Thus, the 1-year mortality in the patient population was 11 times higher than in the control population (2%).

The mortality at the end of the follow up was 46% in the patient population versus 18% in the control group, thus representing a 2.6-fold higher mortality in the patient population at approximately 12 years. The mean survival time was 7.7 (95% confidence interval [CI] 7.6-7.9) years in the patient cohort and 10.4 (95% CI 10.4-10.5) years in the control cohort.

To assess the differences in mortality after early deaths due to trauma, we separately analyzed patients surviving at least 1 year post-trauma (n=2 781). The control group contained controls for those patients who survived at least 1 year (n=27 342). The Kaplan-Meier survival analysis is shown in Figure 3. The long-term survival for the patients who survived at least 1 year post-trauma is constantly lower than in the control population. The mean survival time in the patient cohort was 9.8 (95% CI 9.7-10.0) years and 10.9 (95% CI 10.8-10.9) years in the control cohort. At the end of the follow-up (11 years and 7 months), the patient group had a cumulative mortality of 31% compared with 14% in the control group. The long-term mortality after a major trauma was 2.2-fold higher in this subgroup.

The cumulative mortality increases annually approximately 2.9% in the patient group and 1.3% in the control group.

Factors associated with late mortality (Cox regression analysis)

To determine the factors associated with late mortality, we used Cox regression analysis for the patients who survived at least 1 year post-trauma. Results of the Cox regression analysis are shown in Table 2.

The survival curves for these groups are shown in Figure 3. Factors associated with increased late mortality were male gender (hazard ratio [HR] 1.308, 95% CI 1.069-1.600); age (1.041, 1.033-1.050); long-term unemployment (2.484, 1.143-5.398); ASA grade 2 (1.781, 1.320-2.404), ASA grade 3-4 (2.380, 1.651-3.431), or ASA grade unknown (1.764, 1.288-2.417); transfer to another hospital ICU or HDU (1.460, 1.036-2.056); and head AIS 5 or 6 (1.627, 1.237-2.139).

The only factor associated with decreased mortality was full insurance coverage (HR 0.564, 95% CI 0.422-0.752). The patients with full insurance coverage were younger (40.0±19.0 vs. 51.5±19.2 years, $p < 0.001$), had less severe TBI (head AIS 1.0±1.1 vs. 1.8±2.0, $p < 0.001$), and were more often healthier (proportion of patients with ASA 1, 50.8% vs. 29.4%, $p < 0.001$) than patients without full insurance coverage. In addition, the fraction of long-term unemployed persons was 3.9% in patients with full insurance coverage and 7.4% in patients without ($p < 0.001$). The proportion of males was slightly higher in the full insurance coverage group (76.5% vs. 70.6%, $p < 0.001$) and were more often discharged to another hospital ICU or HDU (18.8% vs. 12.0%, $p < 0.001$).

Causes of death

The causes for late mortality were compared between patients who survived at least 1 year and their controls. In these groups, death certificate information was available for 472/517 (91.3%) patients and 3188/3512 (90.8%) controls. The cause of death was disease in 73.3% in the patient group and 93.6% in the control group. Accidents were more often the cause of death in the patient population than in the control population (21.2% vs. 4.1%). Suicide was the cause of death in 3.0% of the patients and 1.1% of the controls. All other causes of death represented 2.5% in the patient population and 1.2% in the control population. The difference in distribution of the cause of death between the patient and the control groups was statistically significant ($p < 0.001$).

Cancer was the primary cause of death in 11.9% of the patients and in 23.3% of the control population. Poisoning was the primary cause of death in 2.8% of the patients and 1.1% of the control population.

We also reviewed the medical records for the 100 (21.2%) patients who died in an accident at least 1-year post-trauma. A new accident was the cause of death at in least 49 cases. All of these 49 deaths were due to brain injury. These patients were 51.9 (±17.0) years old (range 14-93). In 16 cases, the cause of death was pneumonia or other infection in patients with either very severe brain injury or high spinal cord injury. In 35 cases, the relationship between death to the index injury was uncertain due to insufficient data. The cause of death due to a new accident in patient population was at least 10.4%, which is 2.5-fold higher than in the control group.

Discussion

This study revealed a significant increase in the long-term mortality of major blunt trauma patients compared to age-, sex-, and county of residence-matched controls. To the best of our knowledge, this is the first study to be published with a follow-up this long, patients this severely injured, and a cohort size and control group this large.

According to previous research, the long-term mortality of trauma patients has varied from 9.8% to 16.8% at 1 year and from 16% to 20.1% at 3 years [6,9]. The mortality of trauma patients continuously increased when compared with a control population up to 3 years (16% vs. 5.9%) [6]. The mortality of our patient cohort was high at 1 year (22%), which is explained by the severe injuries in our patients. Furthermore, we only included blunt trauma patients, whereas other studies [5-7,9] also included penetrating injuries. Given the differences in patient populations, results from previous studies are not directly comparable to our results.

In US trauma patients, mortality after discharge was associated with a new trauma in 33% of deaths, more often in younger patients [5]. In our study, accidents were more often the cause of death in the patient population than in the control population (21.2% vs. 4.1%). At least half of these deaths in the patient group were due to a new accident leading to a severe brain injury. In cases with accident as the cause of death, the Finnish death certificate data from administrative registries does not provide the date of the accident. Thus, we were not able to definitely conclude directly from the death certificates whether the accident was due to the index injury or due to an independent event. However, the ICD-10 codes in the death certificates were compared to the ICD-10 codes in the trauma registry in patients with accident as the cause of death (n=100).

The factors associated with long-term mortality after a major trauma are different from those associated with short-term mortality. We wanted to emphasize the effect of trauma in long-term mortality. Therefore, the second analysis started at 1 year after the injury and ended at 11.7 years. This eliminates the effects of early mortality. The survival curves for those who survived at least 1 year post-trauma remains rather constant in both the patient and control groups.

As in previous studies [13], age and gender were also associated with long-term mortality in our patient cohort. The comorbidity burden of the patients has also been previously linked to increased post-traumatic mortality [13]. The association of a high ASA grade to the long-term mortality in this study is suggestive of a similar finding, although we lacked comorbidity information. The effect of head AIS on long-term mortality is controversial. Davidson et al. observed an association with increased mortality, whereas Wong et al. observed an association between high head AIS with higher mortality at 1 year but not at 3 years after the injury [6,13].

Discharge to rehabilitation facilities or to a skilled nursing facility is associated with increased long-term mortality [6]. Although we did not have similar findings in our study, we found an association between patient discharge to another hospital ICU or HDU with higher long-term mortality. The most likely explanation for this is the Finnish healthcare system, where the patients with extended ICU care and poor recovery prognosis are transferred to stepdown ICUs or HDUs in smaller hospitals after acute ICU care in the university hospital. Thus, the need for a stepdown ICU or HDU is an indicator for poorer outcome due to poorer prognosis.

The only factor associated with decreased mortality was full insurance coverage. Lack of insurance has also previously been linked to increased mortality [15,16] in trauma patients. In the Finnish healthcare system, insurance coverage may influence the amount and frequency of physiotherapy, compensation for loss of income, and funding for re-education to another occupation. These issues may have an effect on the physical and mental well-being of the patients after a major trauma.

An interesting finding was that the non-trauma controls had an almost 2-fold higher cancer mortality. Most of our major blunt trauma patients are examined with whole-body trauma CT and it is possible that there are incidental findings in this extensive imaging. Trauma patients also have follow-up visits after trauma and therefore possible symptoms of malignant disease may be detected earlier than in the control group.

The strengths of this study were the long follow-up time and the large study cohort and control group. Governmental administrative registers have high coverage of Finnish citizens. Thus, mortality and socioeconomic data for patients and controls were high in quality and near complete. Due to differences in health policies and health care systems and their possible effect on outcomes, we do not know whether our results can be generalized. As we linked the data of multiple different databases, we did not encounter problems related to failure to follow-up as all the mortality data were available from Finnish health authorities and the validated trauma registry [17,18] was used to identify the patient cohort.

There are some weaknesses with the retrospective register study design. The comorbidity burden of the patients is unknown as it is not collected in our trauma registry. However, the trauma registry contains pre-injury ASA grading of the patients, which provides an estimate of the patients' health status before the injury. Our trauma registry does not contain information on multi-organ failure, which is associated with increased long-term mortality in trauma patients [19]. We do not have any information on several factors that contribute to patient health and long-term mortality, such as smoking, alcohol consumption, or body mass index. Due to the lack of matching by comorbidities, smoking, and socioeconomic status, we used a high number of controls to overcome this problem. We only examined a limited number of parameters in Cox regression analysis and some important factors may be missing. We did not aim to create a prediction model for late mortality. Due to the large study population, even small differences can become statistically significant. The possible clinical significance should be considered when interpreting our results even in findings with statistical significance.

Conclusion

Major trauma has a significant effect on the short-term but also on the long-term mortality of the major trauma patients. According to our results, short-term mortality is an insufficient measure for outcome in major trauma patients as trauma causes increased mortality at least up to 12 years post-trauma. We found multiple associated factors with increased long-term mortality. Full insurance coverage was associated with decreased long-term mortality. No previous studies exist with a control group, with mean ISS/NISS this high, and a population size this large.

Conflicts of Interest

The authors declare that we have no conflicts of interest.

Funding

Funding was received from TuPla funding (Helsinki University Hospital).

References

[1] Pfeifer R, Tarkin IS, Rocos B, Pape HC. Patterns of mortality and causes of death in polytrauma patients--has anything changed? Injury 2009 Sep;40(9):907-11.

[2] Dick WF, Baskett PJ. Recommendations for uniform reporting of data following major trauma--the Utstein style. A report of a working party of the International Trauma Anaesthesia and Critical Care Society (ITACCS). Resuscitation 1999 Oct;42(2):81-100.

[3] Ringdal KG, Coats TJ, Lefering R, Di Bartolomeo S, Steen PA, Roise O, et al. The Utstein template for uniform reporting of data following major trauma: a joint revision by SCANTEM, TARN, DGU-TR and RITG. Scand.J.Trauma.Resusc.Emerg.Med. 2008 Aug 28;16:7-.

[4] Mullins RJ, Mann NC, Hedges JR, Worrall W, Helfand M, Zechnich AD, et al. Adequacy of hospital discharge status as a measure of outcome among injured patients. JAMA 1998 Jun 3;279(21):1727-31.

[5] Claridge JA, Leukhardt WH, Golob JF, McCoy AM, Malangoni MA. Moving beyond traditional measurement of mortality after injury: evaluation of risks for late death. J.Am.Coll.Surg. 2010 May;210(5):788-6.

[6] Davidson GH, Hamlat CA, Rivara FP, Koepsell TD, Jurkovich GJ, Arbabi S. Long-term survival of adult trauma patients. JAMA 2011 Mar 9;305(10):1001-7.

[7] Laupland KB, Svenson LW, Grant V, Ball CG, Mercado M, Kirkpatrick AW. Long-term mortality outcome of victims of major trauma. Injury 2010 Jan;41(1):69-72.

[8] Somersalo A, Paloneva J, Lonnroos E, Heinanen M, Koponen H, Kiviranta I. Sixfold Post-Fracture Mortality in 16- To 30-Year-Old Patients-Suicides, Homicides, and Intoxications Among Leading Causes of Death. Scand.J.Surg. 2018 Dec;107(4):345-9.

[9] Gabbe BJ, Simpson PM, Cameron PA, Ponsford J, Lyons RA, Collie A, et al. Long-term health status and trajectories of seriously injured patients: A population-based longitudinal study. PLoS Med. 2017 Jul 5;14(7):e1002322.

[10] Baker SP, O'Neill B, Haddon W,Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J.Trauma 1974 Mar;14(3):187-96.

[11] Palmer C. Major trauma and the injury severity score--where should we set the bar? Annu.Proc.Assoc.Adv.Automot Med. 2007;51:13-29.

[12] Probst C, Zelle BA, Sittaro NA, Lohse R, Krettek C, Pape HC. Late death after multiple severe trauma: when does it occur and what are the causes? J.Trauma 2009 Apr;66(4):1212-7.

[13] Wong TH, Nadkarni NV, Nguyen HV, Lim GH, Matchar DB, Seow DCC, et al. One-year and three-year mortality prediction in adult major blunt trauma survivors: a National Retrospective Cohort Analysis. Scand.J.Trauma.Resusc.Emerg.Med. 2018 Apr 18;26(1):28.

[14] Meyer S. Grading of patients for surgical procedures. Anesthesiology 1941 May(2):281– 4.

[15] Chen H, Scarborough J, Zens T, Brummeyer B, Agarwal S, Haines KL. Race and Insurance Status as Predictors of Bicycle Trauma Outcome in Adults. J.Surg.Res. 2020 Jan;245:198-204.

[16] Zarzaur BL, Stair BR, Magnotti LJ, Croce MA, Fabian TC. Insurance type is a determinant of 2-year mortality after non-neurologic trauma. J.Surg.Res. 2010 May 15;160(2):196-201.

[17] Heinanen M, Brinck T, Lefering R, Handolin L, Soderlund T. How to Validate Data Quality in a Trauma Registry? The Helsinki Trauma Registry Internal Audit. Scand.J.Surg. 2019 Nov 6:1457496919883961.

[18] Heinanen M, Brinck T, Handolin L, Mattila VM, Soderlund T. Accuracy and Coverage of Diagnosis and Procedural Coding of Severely Injured Patients in the Finnish Hospital Discharge Register: Comparison to Patient Files and the Helsinki Trauma Registry. Scand.J.Surg. 2017 Sep;106(3):269-77.

[19] Ulvik A, Kvale R, Wentzel-Larsen T, Flaatten H. Multiple organ failure after trauma affects even long-term survival and functional status. Crit.Care 2007;11(5):R95.