Mortality After Trauma Craniotomy Is Decreasing in Older Adults—A Nationwide Population-Based Study

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■ OBJECTIVE: **No evidence-based guidelines are available for operative neurosurgical treatment of older patients with traumatic brain injuries (TBIs), and no population-based results of current practice have been reported. The objective of the present study was to investigate the rates of trauma craniotomy operations and later mortality in older adults with TBI in Finland.**

■ METHODS: **Nationwide databases were searched for all admissions with a TBI diagnosis and after trauma craniotomy, and later deaths for persons aged ≥60 years from 2004 to 2018.**

■ RESULTS: **The study period included 2166 patients (64% men; mean age, 70.3 years) who had undergone TBI-related craniotomy. The incidence rate of operations decreased with a concomitant decrease in adjusted mortality (30-day mortality, $P < 0.001$; 1-year mortality, $P < 0.001$) and increase in mean patient age ($R^2 = 0.005$; $P < 0.001$) during the study period. The cumulative mortality was 25% at 30 days and 38% at 1 year. The comorbidities increasing the hazard for 30-day mortality were diabetes, a history of malignancy, peripheral vascular disease, and a history of myocardial infarction. For 1-year mortality, the comorbidities were heart failure and a history of myocardial infarction. Evacuation of an epidural hematoma decreased the hazard for mortality. In contrast, evacuation of an intracerebral hematoma and decompressive craniectomy increased the risk at both 30 days and 1 year.**

■ CONCLUSIONS: **Among older adults in Finland, the rate of trauma craniotomy and later mortality has been decreasing although the mean age of operated patients has been increasing. This can be expected to be related to an improved understanding of geriatric TBIs and, consequently, improved selection of patients for targeted therapy.**

INTRODUCTION

Older adults are the fastest growing age group worldwide, and the occurrence of traumatic brain injuries (TBIs) increases with increasing age.[1] This process has significant effects on societal services, especially healthcare. Finland has one of the highest incidence rates of TBI-related deaths in Europe,[2,3] and the rate has been constantly increasing among older citizens.[1]

Older adults experience less favorable outcomes and greater mortality after TBIs.[4] Chronic subdural hematoma (SDH) is one of the most common neurosurgical conditions resulting from the increased risk of falls among the growing group of older individuals.[5,6] The modern technique for evacuation of chronic SDH is mini-invasive craniostomy. Despite this, the 1-year mortality associated with chronic SDH has been reported to be as high as 13%–32% among older people.[6-8] However, the most significant mortality burden has been associated with older patients who have undergone trauma craniotomy, especially evacuation of an acute SDH. The 30-day mortality rate for patients with acute SDH has

Key words
- Craniotomy
- Elderly patients
- Mortality
- Outcome
- Traumatic brain injury

Abbreviations and Acronyms
CT: Computed tomography
EDH: Epidural hematoma
HR: Hazard ratio
ICH: Intracerebral hematoma
NOMESCO: Nordic Medico-Statistical Committee
SDH: Subdural hematoma
TBI: Traumatic brain injury
THL: National Institute for Health and Welfare, Finland

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been reported to range from 27% to 70% in different cohorts.[9] A debate has been ongoing regarding whether older patients will really benefit from major neurotrauma surgery,[10-12] especially given that older age has been associated with many adverse events postoperatively.[4] In the absence of evidence-based guidelines, some trauma centers have set age-based cutoffs for admissions and neurosurgical interventions for older adults,[10,13] and some centers will perform neurosurgical interventions without predefined guidelines and assess patients on a case-by-case basis.[4,14]

From the current literature, it is difficult to conclude how the mortality rates after acute trauma craniotomy have changed on a broader scale over time. In addition, the results from single-center studies could have been skewed by local practices and guideline interpretations. Thus, we conducted a 15-year nationwide population-based study to investigate the changes in mortality after trauma craniotomy for patients aged ≥60 years in Finland.

METHODS

Study Population and Data Search

The Care Register for Health Care (held by the National Institute for Health and Welfare [THL], Helsinki, Finland), a mandatory database for all public healthcare hospital admissions in mainland Finland, was searched for all admissions with a TBI diagnosis (International Classification of Disease, 10 revision, codes S06*) and trauma craniotomy (Nordic Medico-Statistical Committee [NOMESCO] codes[15] AAD00, AAD05, AAD15, and AAK80) for patients aged ≥60 years from January 1, 2004 to December 31, 2018. Thus, patients with chronic subdural hematomas were not included in the present study. Information on admission and operation dates, patient demographics (i.e., gender, age, comorbidities), and operations are included in the register's discharge data.[16]

All hospitals in Finland that provide care for patients with acute TBIs necessitating acute head computed tomography (CT) imaging were included in the search. One admission per patient per study period was included. The mortality data for the admitted patients were obtained from the mandated-by-law Statistics Finland database covering all deaths of Finnish citizens (mortality data available until December 31, 2018). Hospital transfers related to a particular episode of a hospitalization were combined as 1 admission for the length of stay analysis. The comorbidities were selected and searched as described previously.[17]

Trauma Craniotomy

Only those neurosurgical procedures that included major trauma craniotomy were included in the present study. The procedures in question were craniotomy and evacuation of an epidural hematoma (EDH; NOMESCO code, AAD00), craniotomy and evacuation of an acute SDH (NOMESCO code, AAD05), craniotomy and evacuation of a traumatic intracerebral hematoma (ICH; NOMESCO code, AAD15), and decompressive hemicraniectomy (NOMESCO code, AAK80).[15] Mini-invasive procedures that included chronic hematoma evacuation via a small burr hole (NOMESCO codes, AAD10 and AAD12), ventriculostomy (NOMESCO code, AAF00), revision of a penetrating injury (NOMESCO code, AAD30), and elevation of an impression fracture (NOMESCO code, AAD40) were not included.

Statistical Analysis

Continuous variables were analyzed using the t test and linear regression. Mortality was analyzed using the Kaplan-Meier method and Cox regression (excluding 5 patients with missing follow-up data). The incidence was analyzed with negative binomial regression with a logarithm of corresponding age-, gender-, and year-specific populations at risk as an offset parameter. Significance was inferred at 5%. The SAS system, version 9.4 (SAS Institute Inc., Cary, North Carolina, USA) and GraphPad Prism, version 8.0 (GraphPad Software, San Diego, California, USA) were used for the statistical analyses.

Ethical Approval and Informed Consent

The present study was a retrospective registry study and no approval from an ethical committee was required. The THL and Statistics Finland approved the present study (permission nos. THL/2245/5.05.00/2019 and TK-53-484-20). Our study was a retrospective register study; thus, no informed patient consent was required, and the participants were not contacted. The legal basis for the processing of personal data was public interest and scientific research [EU General Data Protection Regulation 2016/679, Article 6(1)(e) and Article 9(2)(j); Data Protection Act, Sections 4 and 6].

Data Availability Statement

Because of national data protection legislation, the register data used in the present study cannot be shared without applying for permission to use the data with a specific study protocol and scientifically justified study questions.

RESULTS

From 2004 to 2018, 2166 older adults (1376 men; 64%) aged ≥60 years had undergone trauma craniotomy after a TBI in Finland. The mean age of these patients was 71.8 ± 7.9 years, with an annual variance in the mean age from 70.1 to 73.6 years, with an increasing trend ($R^2 = 0.005$; $P < 0.001$) during the study period. In terms of comorbidities, alcohol abuse was more common in the men, and heart failure, hypertension, psychotic disorder, and systemic rheumatic disease were more common in the women (Table 1).

A total of 110 patients (5.1%) had undergone surgery for EDH, 1796 (83%) for acute SDH, and 311 (14%) for traumatic ICH, and 24 (1%) had undergone decompressive craniectomy. Evacuation of an EDH was more common for the women, and evacuation of an ICH was more common for the men. No changes were found in the distribution of the trauma craniotomy types during the study period (Table 1). The mean hospital length of stay after trauma craniotomy was 9.2 ± 8.6 days for the men, 8.2 ± 6.9 days for the women, and 8.8 ± 8.1 days overall.

Incidence Rates of Trauma Craniotomy

During the 15-year study period, the incidence rate for trauma craniotomy was highest for those aged 70−79 years for both genders (Figure 1). The incidence rate of surgery decreased over time when analyzed for both genders in 5-year intervals (Figure 2A). The incidence had decreased most prominently for the patients aged 60−69 years and more subtly for those aged

Table 1. Patient Characteristics Stratified by Gender

Variable	All (*n* = 2166)	Men (*n* = 1376)	Women (*n* = 790)	*P* Value
Age (years)	71.8 ± 7.9	70.3 ± 7.7	74.3 ± 8.2	<0.0001*
Comorbidity				
Alcohol abuse	372 (17.2)	303 (22.0)	69 (8.7)	<0.0001*
History of anemia	53 (2.5)	28 (2.0)	25 (3.2)	0.101
Atrial fibrillation	555 (25.6)	340 (24.7)	215 (27.2)	0.199
Cerebrovascular disease	826 (38.1)	524 (38.1)	302 (38.2)	0.946
Chronic pulmonary disease	194 (8.7)	119 (8.7)	75 (9.5)	0.507
Coagulopathy	32 (1.5)	18 (1.3)	14 (1.8)	0.389
Dementia	139 (6.4)	81 (5.9)	58 (7.3)	0.183
Diabetes	319 (14.7)	209 (15.2)	110 (13.9)	0.424
Heart failure	271 (12.5)	153 (11.1)	118 (14.9)	0.010*
Hypertension	736 (34.0)	434 (31.5)	302 (38.2)	0.002*
Liver disease	74 (3.2)	46 (3.3)	28 (3.5)	0.804
History of malignancy	275 (12.7)	181 (13.2)	94 (11.9)	0.398
History of MI	131 (6.1)	84 (6.1)	47 (6.0)	0.884
Peripheral vascular disease	136 (6.3)	90 (6.5)	46 (5.8)	0.507
Psychotic disorder	52 (2.4)	26 (1.9)	26 (3.3)	0.040*
Renal failure	51 (2.4)	30 (2.2)	21 (2.7)	0.480
Systemic rheumatic disease	95 (4.4)	36 (2.6)	59 (7.5)	<0.0001*
Surgical procedure				
AAD00	110 (5.1)	55 (4.0)	55 (7.0)	0.003*
AAD05	1796 (82.9)	1134 (82.4)	662 (83.8)	0.410
AAD15	311 (14.4)	223 (16.2)	88 (11.1)	0.001*
AAK80	24 (1.1)	19 (1.4)	5 (0.6)	0.110
Study era				0.995
2004—2008	720 (33.2)	458 (33.3)	262 (33.2)	
2009—2013	758 (35.0)	482 (35.0)	276 (34.9)	
2014—2018	688 (31.8)	436 (31.7)	252 (31.9)	

MI, myocardial infarction; AAD00, craniotomy and evacuation of epidural hematoma; AAD05, craniotomy and evacuation of subdural hematoma; AAD15, craniotomy and evacuation of traumatic intracerebral hematoma; AAK80, decompressive craniectomy.
*Statistically significant.

70—79 years but did not show a clear trend over time for the oldest patients (age, ≥80 years; Figure 2B).

Mortality After Trauma Craniotomy

The probability of death increased with increasing patient age (Table 2 and Figure 3). The cumulative mortality after trauma craniotomy was 13% at 7 days, 25% at 30 days, 31% at 90 days, 38% at 1 year (Figure 3), 41% at 2 years, and 55% at 5 years.

The 30-day and 1-year mortality were investigated first in a univariate model and then in a multivariate model that included the age groups, study eras, comorbidities, and trauma craniotomy types. In the 30-day and 1-year univariate models, the latest study era (2014—2018) was associated with a decreased hazard ratio (HR) for mortality when the first study era (2004—2008) was used as the reference. When 30-day and 1-year mortality were analyzed in the multivariate models, a decrease during the study period was observed (Tables 2 and 3).

In the 30-day multivariate model, the comorbidities that increased the HR for death were diabetes, a history of malignancy, peripheral vascular disease, and a history of myocardial infarction (Table 2). In the 1-year multivariate model, the comorbidities were heart failure and a history of myocardial infarction (Table 3). For both the 30-day and the 1-year multivariate models, evacuation of an EDH decreased the HR for death. In contrast, evacuation of

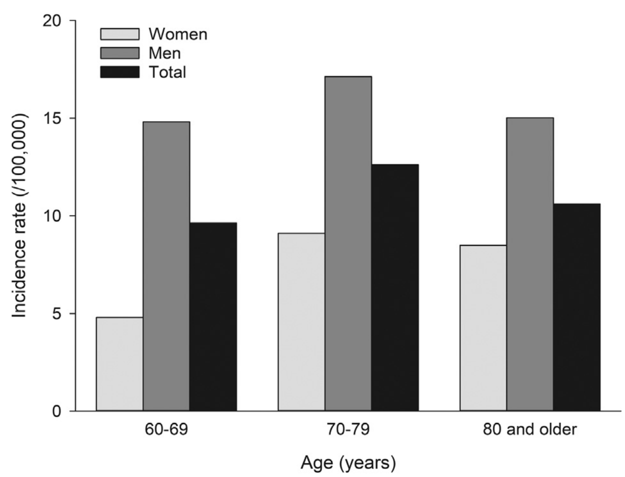

Figure 1. Incidence rates of trauma craniotomy stratified by age group.

an ICH and decompressive craniotomy increased the risk of death, with the highest HRs of all the variables (Tables 2 and 3).

DISCUSSION

In the present 15-year nationwide population-based study, we investigated the rates of trauma craniotomy and later mortality in older Finnish citizens. The main finding of the present study was that the rate of trauma craniotomy had temporally decreased after excluding the oldest age group, with a concurrent decrease in the adjusted 30-day and 1-year mortality and increase in the mean age of the surgically treated patients aged ≥60 years. The cumulative mortality was 25% at 30 days and 38% at 1 year. Cardiovascular diseases dominated the comorbidities that increased the risk of death after trauma craniotomy.

The aging population is rapidly increasing worldwide.[18] We recently reported that the incidence rate of geriatric TBIs has been increasing in Finland, although overall mortality has remained stable and the rate of all acute neurosurgical operations has decreased for patients aged ≥70 years.[1] However, for patients aged ≥85 years, the incidence of fatal TBIs has increased—the latter age group is the only one in the Finnish population for which mortality after TBI has lately increased.[3] Most TBIs are mild in severity,[19] and this also applies to TBIs in older patients.[20,21] However, more severe TBIs also affect this fragile group of patients. The reported data are scarce regarding the operative treatment of moderate to severe TBI in older patients. Small, single-institution series have yielded variable results. This creates a vicious circle, because with the minimal body of reported data, it has not been possible to create evidence-based guidelines. Thus, older patients with TBI will undergo various degrees of treatment with heterogeneous inclusion criteria among different centers even in the same country. It is common in high-income countries that many neurosurgical centers will have set age-based cutoffs for major neurosurgical interventions and intensive care admissions for older patients with TBIs.[10,13] The theoretical premise for the present study was to examine the effects of the ongoing demographic changes in Finnish society and current neurosurgical practice on mortality after TBI that necessitates major neurotrauma surgery in older patients. Efficacy studies of invasive neurotrauma treatment of older patients are scarce. Thus, we approached this question by examining a surrogate marker: mortality over time after trauma craniotomy.

The mortality rates for older patients have been grim after the most common major trauma craniotomy, evacuation of an acute SDH. In a systematic review of 7 studies and 396 older patients, the 30-day mortality rates were 27%—70%.[9] The wide range could

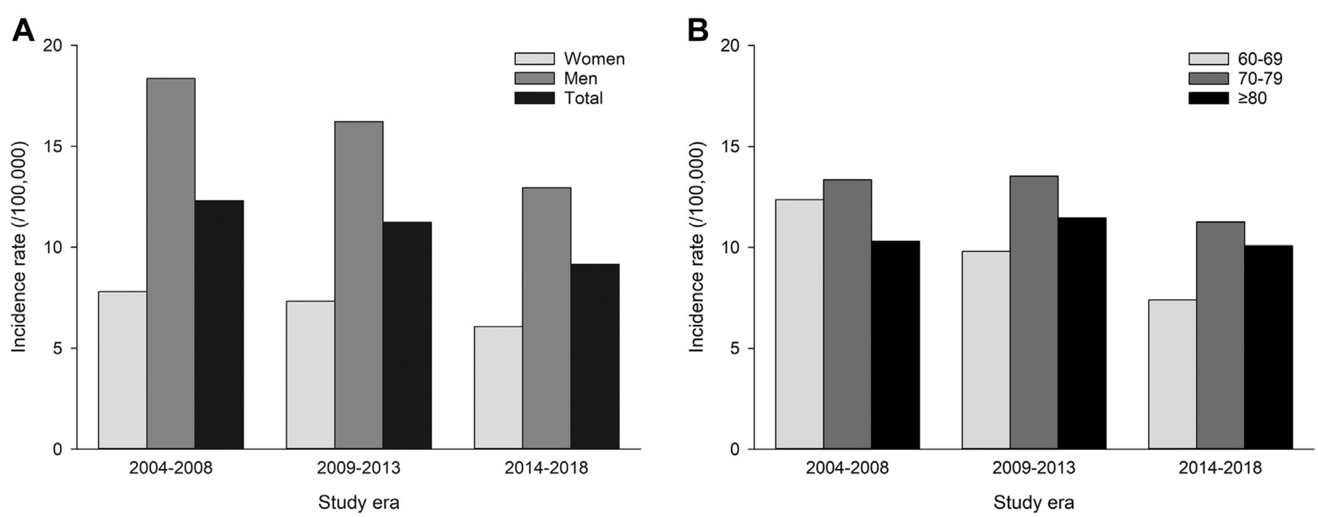

Figure 2. Incidence rates of trauma craniotomy stratified by study era and (**A**) gender and (**B**) age.

Table 2. Thirty-Day Mortality

	Univariate			Multivariate		
Variable	***P* Value**	**HR**	**95% CI**	***P* Value**	**HR**	**95% CI**
Male gender	0.246	1.11	1.93–1.33	0.092	1.17	0.97–1.41
Age group	0.001*			0.006*		
60–69 years	Ref			Ref		
70–79 years	0.054	1.21	0.10–1.47	0.394	1.09	0.89–1.35
≥80 years	<0.001*	1.54	1.23–1.92	0.002*	1.48	1.15–1.90
Study era	0.053			<0.001*		
2004–2008	Ref			Ref		
2009–2013	0.340	0.91	0.74–1.11	0.032*	0.80	0.65–0.98
2014–2018	0.016*	0.77	0.62–0.95	<0.001*	0.62	0.49–0.78
Alcohol abuse	0.007*	0.72	0.56–0.91	0.157	0.82	0.63–1.08
Anemia	0.469	1.20	0.73–1.98	0.543	1.17	0.70–1.96
Atrial fibrillation	0.065	1.19	0.99–1.43	0.935	0.99	0.80–1.22
Cerebrovascular disease	0.152	1.13	0.96–1.35	0.665	1.04	0.87–1.24
Chronic pulmonary disease	0.180	1.21	0.92–1.59	0.457	1.11	0.84–1.48
Coagulopathy	0.047	1.79	1.01–3.17	0.108	1.62	0.90–2.93
Dementia	0.617	1.09	0.78–1.51	0.917	1.02	0.73–1.42
Diabetes	0.001*	1.42	1.15–1.76	0.021*	1.31	1.04–1.66
Heart failure	0.001*	1.46	1.17–1.83	0.081	1.26	0.97–1.63
Hypertension	0.069	1.18	0.99–1.40	0.983	1.00	0.82–1.22
Liver disease	0.958	1.01	0.64–1.60	0.531	1.17	0.72–1.90
History of malignancy	0.009*	1.36	1.08–1.71	0.010*	1.37	1.08–1.73
Peripheral vascular disease	0.002*	1.59	1.19–2.13	0.032*	1.40	1.03–1.92
History of MI	0.001*	1.64	1.22–2.19	0.038*	1.39	1.02–1.88
Psychotic disorder	0.771	0.92	0.52–1.63	0.824	0.94	0.52–1.68
Systemic rheumatic disease	0.424	1.17	0.80–1.73	0.493	1.15	0.77–1.70
Renal failure	0.005*	1.88	1.22–2.91	0.146	1.42	0.89–2.26
AAD00	<0.001*	0.24	0.12–0.48	0.021*	0.40	0.18–0.87
AAD05	0.160	1.18	0.94–1.49	0.077	1.52	0.96–2.41
AAD15	0.078	1.22	0.98–1.53	0.010*	1.77	1.15–2.74
AAK80	0.196	1.55	0.80–3.01	0.038*	2.09	1.04–4.19

HR, hazard ratio; CI, confidence interval; Ref, reference variable; MI, myocardial infarction; AAD00, craniotomy and evacuation of epidural hematoma; AAD05, craniotomy and evacuation of subdural hematoma; AAD15, craniotomy and evacuation of traumatic intracerebral hematoma; AAK80, decompressive craniectomy.
*Statistically significant.

have resulted from the variabilities in treatment strategies and case mix. The combined 30-day mortality rate of the 4 trauma craniotomy types was 25% in the present study. The results are comparable in that most of the procedures in the present study were evacuations of acute SDH. The in-hospital mortality rate was 18% in a recent large retrospective study of National Trauma Data Bank data, including 2508 patients aged ≥65 years who had undergone craniotomy and evacuation of an acute SDH.[22] This rate, in turn, is comparable to the 7-day mortality rate in the present study, which was 13%.

Although research on this topic is scarce, it seems that the treatment practices for geriatric TBI have been changing in Finland. The rate of elderly patients treated at the largest neurosurgical intensive care unit in Finland had significantly increased from 1999

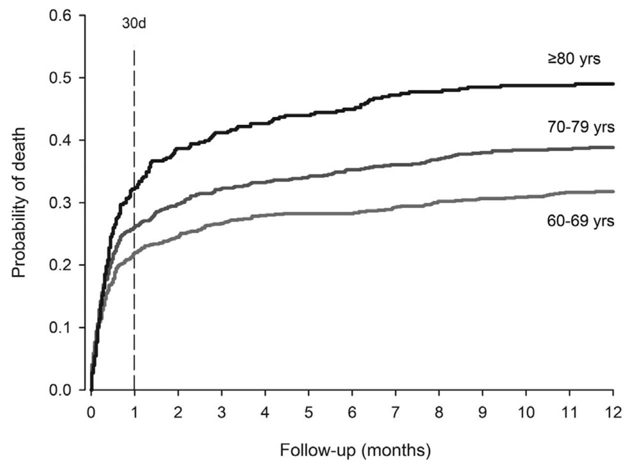

Figure 3. Probability of death after trauma craniotomy for different age groups over time.

to 2015. Of these patients, more than one half had undergone trauma craniotomy. However, the percentage of operations had decreased from 74% to 42% over time.[23] We recently reported that of all Finnish neurosurgical centers, overall, 25% of the hospitalized patients aged ≥70 years had undergone an acute neurosurgical operation, including mini-invasive and major procedures from 2004 to 2014.[1] An annual decrease of 1.1% was found in the odds for surgery during the study period.[1] A similar change was observed when only major operations—trauma craniotomies—were examined overall from 2004 to 2018 in the present study. The only group of patients for whom the rate of operations did not decrease was the oldest age group. From the present results, it is not possible to determine why the incidence of trauma craniotomy had decreased during the study period. One of the reasons is probably that the incidence of TBIs has been constantly increasing in older people, for whom the most common injury mechanism is a fall, and the injuries will be, for the most part, mild.[1,4,20,21] Another reason might be that as the population ages, falls have been increasing among older individuals, for whom surgical treatment for mass lesions is withheld when the prognosis has been deemed pessimistic owing to other comorbidities or age. We also observed that the incidence for trauma craniotomy was highest for the age group of 70—79 years during the study period. We hypothesized that for those aged 70—79 years, individuals have a greater risk of TBI from falling than younger individuals. However, because of their lower disease burden and longer life expectancy, the younger patients will be more suitable for aggressive surgery and intensive care than their older counterparts. The reasons for the unchanged rate of surgery in the oldest age group warrant further research.

In the univariate models, an increased risk of both 30-day and 1-year mortality was associated with age ≥80 years, alcohol abuse, heart failure, a history of malignancy, peripheral vascular disease, a history of myocardial infarction, and renal failure. A decreased risk was associated with the latest study era. In the multivariate models, cardiovascular diseases and a history of malignancy increased the risk of both 30-day and 1-year mortality. Moreover, in all models, evacuation of an EDH was associated with a decreased risk of mortality compared with other types of trauma craniotomy. This finding is in line with the finding from the vastly validated IMPACT (International Mission for Prognosis and Analysis of Clinical Trials in TBI) prognostication model[24] and outcome prediction-weighted head CT scores (Rotterdam CT score,[25] Helsinki CT score,[26] and Stockholm CT score[27]). Evacuation of an ICH and decompressive craniectomy were associated with the highest risk of death of all the variables, which reflects the severity of the underlying pathologies. We observed that the rate of trauma craniotomy performed has been decreasing over time. Concurrently, mortality has been declining despite a steady increase in the average age of the surgically treated patients. It is not possible to show distinct reasons for these changes from our data. In principle, international guidelines are followed in Finnish academic neurosciences centers, which were slightly updated during the research years. However, it is likely that the favorable results obtained are related to the improved patient selection for different treatment strategies owing to the accumulated neurotrauma evidence.

For older patients, preinjury health (including preexisting morbidity and functional performance) might be a better predictor of outcomes and response to treatment than patient age and TBI severity. Without proper guidelines and evidence-based guidance, the management of TBI in older individuals has remained challenging. Clinicians are frequently faced with difficult ethical decisions on how to treat this growing and challenging patient population. The allocation for different treatment strategies in neurointensive care[28] and neurosurgical care[29] require complex medical judgment. Although age, Glasgow coma scale score (especially its motor component), and pupil reactivity are strong outcome predictors for patients of all ages,[30] a paucity of literature elucidating the baseline risk factors predictive of outcomes for older patients with TBI is available. Preexisting conditions are common in older patients with TBI. A greater comorbidity burden at the time of a TBI is associated with increased 1-year mortality.[31] The presented results have highlighted the effect of cardiovascular diseases on the risk of death after TBI.

The strengths of the present study were the robust Finnish obligatory databases and nationwide population-based design. To the best of our knowledge, the present study is the first to investigate mortality after acute trauma craniotomy for older adults in a setting that comprised all Finnish national centers with neurosurgical services. The present results complement earlier research from Finland and elucidate the continuity of the epidemiological changes in TBI in older patients. Another strength was that the included NOMESCO codes are specific for the intracranial lesion types. Owing to the retrospective and administrative nature of the present study, some uncertainty existed regarding the data. We were unable to study the different severities of TBI separately, because the data search used the International Classification of Diseases, 10th revision, and NOMESCO codes. The changes in the observed rates do not allow conclusions to be drawn regarding whether the changes in local or national practices and demographics had led to the changes in mortality. Finally, we did not have functional or quality-of-life outcome measures available; hence, we focused purely on mortality.

Table 3. One-year Mortality

	Univariate			Multivariate		
Variable	***P* Value**	**HR**	**95% CI**	***P* Value**	**HR**	**95% CI**
Male gender	0.246	1.11	0.93–1.33	0.016	1.21	1.04–1.41
Age group	0.001*			<0.001*		
60–69 years	Ref			Ref		
70–79 years	0.054	1.21	0.10–1.47	0.041	1.19	1.01–1.42
≥80 years	<0.001*	1.54	1.23–1.92	<0.001*	1.64	1.34–2.02
Study era	0.053			<0.001*		
2004–2008	Ref			Ref		
2009–2013	0.340	0.91	0.74–1.11	0.088	0.86	0.73–1.02
2014–2018	0.016*	0.77	0.62–0.95	<0.001*	0.65	0.54–0.79
Alcohol abuse	0.007*	0.72	0.56–0.91	0.273	0.89	0.71–1.10
Anemia	0.469	1.20	0.73–1.98	0.150	1.35	0.90–2.01
Atrial fibrillation	0.065	1.19	0.99–1.43	0.925	0.99	0.83–1.18
Cerebrovascular disease	0.152	1.13	0.96–1.35	0.408	1.06	0.92–1.23
Chronic pulmonary disease	0.180	1.21	0.92–1.59	0.641	1.06	0.83–1.34
Coagulopathy	0.047*	1.79	1.01–3.17	0.403	1.26	0.73–2.16
Dementia	0.617	1.09	0.78–1.51	0.053	1.29	0.10–1.66
Diabetes	0.001*	1.42	1.15–1.76	0.156	1.15	0.95–1.40
Heart failure	0.001*	1.46	1.17–1.83	0.005*	1.35	1.10–1.67
Hypertension	0.069	1.18	0.99–1.40	0.853	0.96	0.84–1.16
Liver disease	0.958	1.01	0.64–1.60	0.582	1.12	0.75–1.68
History of malignancy	0.009*	1.36	1.08–1.71	0.006	1.32	1.08–1.60
Peripheral vascular disease	0.002*	1.59	1.19–2.13	0.144	1.22	0.93–1.60
History of MI	0.001*	1.64	1.22–2.19	0.006*	1.43	1.11–1.85
Psychotic disorder	0.771	0.92	0.52–1.63	0.593	1.13	0.73–1.74
Systemic rheumatic disease	0.424	1.17	0.80–1.73	0.631	1.09	0.78–1.51
Renal failure	0.005*	1.88	1.22–2.91	0.063	1.45	0.98–2.16
AAD00	<0.001*	0.24	0.12–0.48	0.024*	0.52	0.30–0.92
AAD05	0.160	1.18	0.94–1.49	0.218	1.28	0.86–1.91
AAD15	0.078	1.22	0.98–1.53	0.029*	1.52	1.04–2.22
AAK80	0.196	1.55	0.80–3.01	0.003*	2.38	1.35–4.21

HR, hazard ratio; CI, confidence interval; Ref, reference variable; MI, myocardial infarction; AAD00, craniotomy and evacuation of epidural hematoma; AAD05, craniotomy and evacuation of subdural hematoma; AAD15, craniotomy and evacuation of traumatic intracerebral hematoma; AAK80, decompressive craniectomy.

*Statistically significant.

CONCLUSIONS

In the present 15-year population-based study, we found that the rate of trauma craniotomy had decreased, with a concurrent decrease in the adjusted 30-day and 1-year mortality and increase in mean age for older patients in Finland from 2004 to 2018. Cardiovascular diseases dominated the comorbidities that increased the risk of death after trauma craniotomy. To date, the efficacy of treatment of TBIs for older patients has been scarcely studied. These results indicate that although fewer and fewer trauma craniotomies were performed during the 15-year study period, mortality has been declining despite a steady increase in the average age of the treated patients. We believed this was related to an improved understanding of geriatric

TBIs and, consequently, the improved selection of patients for targeted therapy.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Jussi P. Posti: Conceptualization, Writing - original draft, Investigation, Writing - review & editing. **Teemu M. Luoto:** Conceptualization, Investigation, Writing - review & editing. **Päivi Rautava:** Data curation, Writing - review & editing. **Ville Kytö:** Conceptualization, Data curation, Formal analysis, Methodology, Investigation, Visualization, Writing - review & editing, Supervision.

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