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Treatment of Geriatric Traumatic Brain Injury: A Nationwide Cohort Study

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Background: Because of the aging of the Japanese population, traumatic brain injuries (TBI) have increased in elderly adults. However, the effectiveness and prognosis of intensive treatment for geriatric TBI have not yet been determined. Thus, we used nationwide data from the Japan Neurotrauma Data Bank (JNTDB) projects to analyze prognostic factors for intensive and aggressive treatments.

Methods: We analyzed 1,879 geriatric TBI cases (age $\geq$65 years) registered in four JNTDB projects: Project 1998 (P1998) to Project 2015 (P2015). Clinical features, use of aggressive treatment, and 6-month outcomes on the Glasgow Outcome Scale (GOS) were compared among study projects. Logistic regression was used to identify prognostic factors in aggressively treated patients.

Results: The percentage of geriatric TBI cases significantly increased with time-P1998: 30.1%; Project 2004 (P2004): 34.6%; Project 2009 (P2009): 43.9%; P2015: 53.6%, $p<0.0001$). Use of aggressive treatment also significantly increased, from 67.0% in P1998 to 69.3% in P2015 ($p<0.0001$). Less invasive methods, such as trepanation and normothermic targeted temperature management, were more often chosen for geriatric patients. These efforts resulted in a significant decrease in the 6-month mortality rate, from 76.2% in P1998 to 63.1% in P2015 ($p=0.0003$), although the percentage of severely disabled patients increased, from 8.9% in P1998 to 11.1% in P2015 ($p=0.0003$). Intraventricular hemorrhage was the factor most strongly associated with unfavorable 6-month outcomes (OR 3.79, 95% CI 1.78-8.06, $p<0.0001$).

Conclusions: Less invasive treatments reduced mortality in geriatric TBI but did not improve functional outcomes. Patient age was not the strongest prognostic factor; thus, physicians should consider characteristics other than age. (J Nippon Med Sch 2021; 88: 194–203)

Key words: traumatic brain injury, Glasgow Outcome Scale, intraventricular hemorrhage, intracranial pressure

Introduction

In Japan, the age distribution for traumatic brain injury (TBI) is rapidly changing. In past reports from the Japan Neurotrauma Data Bank (JNTDB), the ratio of TBIs in young people as a proportion of the entire population decreased, whereas the ratio of TBIs in elderly adults increased[1]. The number of geriatric TBIs is expected to increase as society ages, which will have a substantial effect on society, including medical economics. In this situation, there is an urgent need for measures to deal with geriatric brain injury, but there is still no specific treatment strategy[2]. Thus, it is important to develop and discuss medical interventions to be adopted by neurotrauma surgeons and evaluate patient outcomes.

The aim of this study was to use nationwide data from the JNTDB projects to identify prognostic factors for intensive and aggressive treatments in these patients. We examine and discuss cases registered in the JNTDB projects (P1998, P2004, P2009, and P2015), including treatments provided to geriatric TBI cases in Japan and patient outcomes. Furthermore, we also examined and discuss how aggressive treatments like surgery, intracranial

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pressure (ICP) monitoring, and active thermoregulation were selected, as indicated by JNTDB data.

Materials and Methods

The Japan Neurotrauma Data Bank

The JNTDB is a Japanese nationwide registry designed to collect and report data on patients with TBI in Japan. This project was initiated by the Japan Society of Neurotraumatology in 1997. The data sheet of the JNTDB was composed of 392 items, including information on the characteristics of the injury and diagnosis, treatment, and complications with respect to treatment outcome[3].

After conducting a pilot study in 1997, a 3-year nationwide study was started in 1998 (P1998). The inclusion criteria were severe TBI in patients (1) with an initial Glasgow Coma Scale (GCS) score of less than eight or (2) a decrease in GCS score within 48 hours of injury onset and the start of treatment. In P1998, data were collected from 1,002 prospective TBI cases. Subsequently, P2004 was performed from January 2004. In P2004, patients of all ages were included, and data were collected from 1,101 prospective cases. P2009 commenced in January 2009, was completed in 2012, and included 1,091 cases. P 2015 was completed in 2018. The P2015 study included data taken from 32 level-one emergency medical centers, and 1,345 patients were added to the database over its duration. All study projects were submitted and approved by the institutional review board of each participating institute. Patients or patient relatives were fully informed about this study with a letter and on the website of each center, and the opportunity to opt-out was provided to all participants.

Study Procedure

This was a retrospective cohort study of data in JNTDB. For our analysis of cases registered in the JNTDB database (P1998: 1998-2001, 10 facilities, 1,002 cases; P 2004: 2004-2006, 19 facilities, 1,101 cases; P2009: 2009-2011, 22 facilities, 1,091 cases; P2015: 2015-2017, 32 facilities, 1,345 cases), the geriatric group included patients 65 years of age or older. We compared aging rate, age, gender, ratio of diffuse brain injury and focal brain injury, GCS score at initial consultation, Injury Severity Score (ISS), length of hospital stay, vital signs, blood gas findings, pupil findings, and computed tomography (CT) findings. For CT findings, we examined the presence of vault fractures, basilar skull fractures, pneumocephalus, traumatic subarachnoid hemorrhage, and intraventricular hemorrhage and compared the proportion of patients with diffuse injury, based on the Traumatic Coma Data Bank (TCDB) classification of Diffuse injury I-IV and the proportion of those with focal injury, based on the presence of an evacuated and non-evacuated mass.

To examine treatment transitions, we compared the proportion of patients managed with different types of treatment, including craniotomy, trepanation, trepanation after craniotomy, barbiturate therapy, active thermoregulation (therapeutic hypothermia, intentional normothermia), and ICP monitoring. We compared aggressive treatment (cases treated with any type of treatment involving craniotomy, trepanation, active thermoregulation, barbiturate therapy, or ICP monitoring) and non-aggressive forms of treatment. The length of hospital stay and GOS score at 6 months after injury were compared among projects as patient outcomes.

The data obtained from P1998, P2004, P2009, and P 2015 were examined retrospectively using univariate analysis to clarify the characteristics of patients with poor outcomes (severe disability, vegetative state, and death) for geriatric brain injury. Prognostic factors for poor outcomes were examined with multiple logistic regression analysis.

The mean value of each item is displayed as mean ± SD, and the t-test was used for two-group comparisons. The chi-square test was used for comparison of categorical data. Analysis of variance was used for four-group comparisons. A P value of less than 0.05 was considered to indicate statistical significance.

Results

Study Population

Using the study criteria, we extracted 1,879 cases from the JNTDB dataset, which was collected over 20 years. Data for 6-month outcome were missing in 421 cases. Therefore, logistic analysis to detect 6-month prognostic factors used data from 1,458 cases (**Fig. 1**).

Transition in Age Composition and Changes in Aging Rate in Each Project

Figure 2 shows the age composition of patients in each project. In P1998, the inclusion criterion for data registration was patients 6 years of age and older. Therefore, in **Figure 2**, the category 0-9 years in P1998 was limited to 6-9 years. P1998 had a bimodal distribution with two clear peaks, at 20-29 years and 60-69 years. However, from P2004, the peak at 20-29 years decreased and the peak at 60-69 years increased, which resulted in a monomodal tendency. Furthermore, in P2015, the number of patients in the age group $\geq$60 years continued to increase. The age distribution peak shifted to 70-79 years

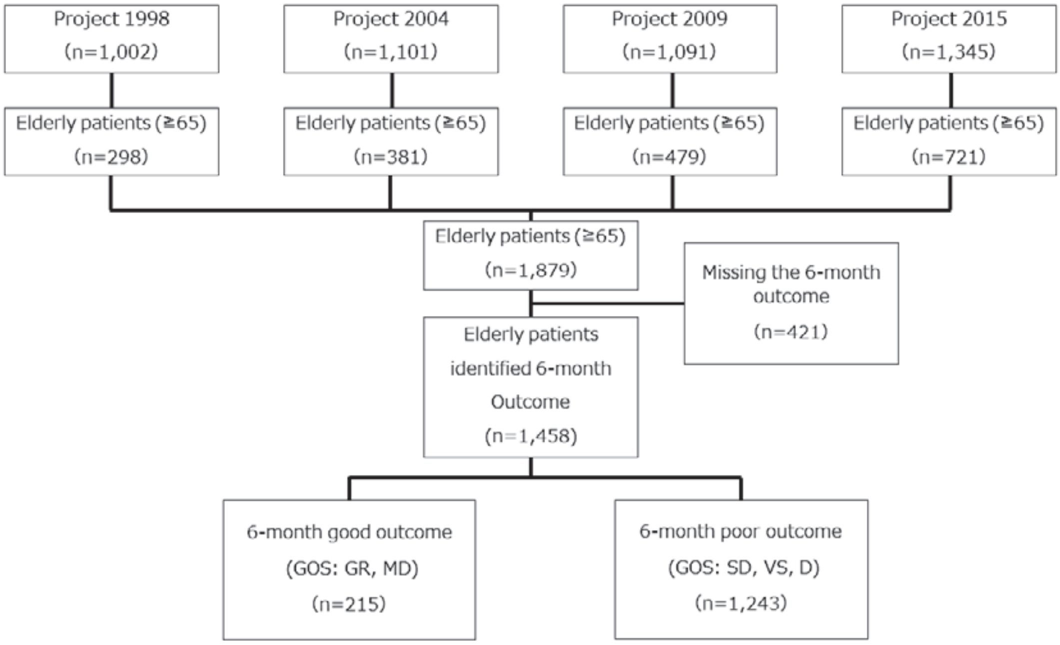

Fig. 1 Study flow diagram.
A total of 1,879 cases were extracted from the dataset of four JNTDB project databases, which were collected over a recent 20-year period. The 6-month outcome data were missing for 421 cases, and data from 1,458 cases were analyzed by logistic regression to identify prognostic factors in elderly TBIs.
Abbreviations: GOS, Glasgow Outcome Scale; GR, good recovery; MD, moderate disability; SD, severely disabled; VS, vegetative state; D, dead.

Fig. 2 Age distribution of patients in the four projects.
The patients in project 1998 were registered from age 6 years; therefore, the youngest age category was 6–9 years. The number of patients older than 60 years rapidly increased.

and changed to a shape with a gentle downward slope toward the younger age groups.

The aging rate (percentage of patients aged ≥65 years) significantly increased across projects (**Fig. 3**), from 30.1% in P1998 to 34.6% in P2004, 43.9% in P2009, and 53.6% in P2015 (p<0.0001). There was a significant increase in the percentage of elderly-elder (age ≥75 years) among elders (P1998: 14.6%, P2015: 33.3%, p<0.0001, **Fig. 3**).

Transition in the Physiology and Anatomical Severity of Geriatric TBI Patients

The general clinical features of geriatric patients with TBI in the four projects are shown in **Table 1**. In P1998, the ratio of males was larger (63.4%) but significantly declined to 52.1%, in P2015. There was also a significant increase in the average age of cases in the elderly group (P 1998: 75.3 ± 7.4 years vs P2015: 77.5 ± 7.6 years, $p<$ 0.0001). The median GCS score on hospital arrival was 5.0 in P1998, which significantly increased to a mean of 6.0 in P2015. These results suggest that the significant increase in motor score in particular might have affected this outcome.

There were no significant differences in heart rate, respiratory rate, body temperature, or pupil findings among patients in the four projects, but there was a significant increase in systolic blood pressure, PaO_2, and $PaCO_2$ on hospital arrival. There was a reduction in ISS, which shows the anatomical severity of the condition-median (IQR): P1998, 25.0 (25.0-27.0) vs P2015, 25.0 (17.0-27.0); p = 0.035)-and, detailed findings from initial CT scans showed a significant reduction in vault fractures and a significant increase in basilar skull fracture and pneumocephalus, traumatic subarachnoid hemorrhage, and intraventricular hemorrhage (IVH) ($p<0.0001$, chi-square test). A comparison of the ratio of diffuse/focal injury showed

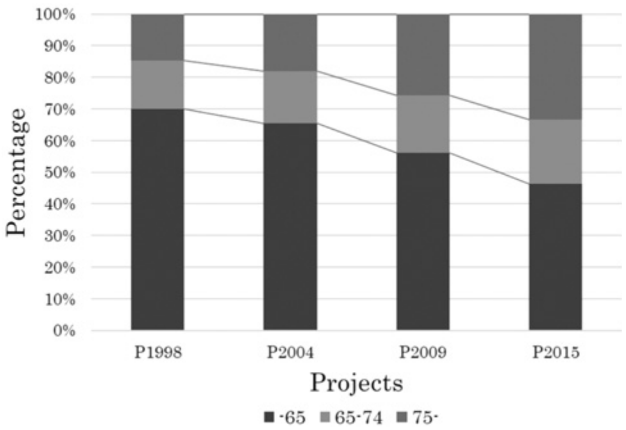

Fig. 3 Percentage of young (<65), younger-elder (65–74 years old), and elderly-elder (≥75) patients in each project period.
In geriatric traumatic brain injury (TBI) populations, the number of elderly-elder geriatric patients (over 75 years of age) has been increasing. Currently in Japan, half of all TBIs occur in patients older than 65 years of age.

Table 1 General clinical features of geriatric traumatic brain injury patients in four projects

Project	1998	2004	2009	2015	*p*-value
N (>65 y.o)	298	381	479	721	
Gender					
Male	189	229	283	376	
Female	103	152	196	345	< 0.0001
Unknown	5	0	0	0	
Age	75.3 ± 7.4	75.4 ± 6.9	77.1 ± 7.5	77.5 ± 7.6	< 0.0001
Physical severity					
GCS score Median (IQR)	5.0 (4.0-8.0)	6.0 (4.0-9.2)	6.0 (4.0-9.0)	6.0 (4.0-9.0)	0.0125
Systolic blood pressure (mm Hg)	140.2 ± 53.9	150.3 ± 49.4	147.0 ± 47.9	150.0 ± 45.3	0.0204
Heart rate (/min)	86.6 ± 31.6	87.4±26.2	86.5±27.0	87.6 ± 26.1	0.8873
Respiratory rate (/min)	19.4 ± 9.0	20.5 ± 8.0	20.3 ± 9.9	19.6 ± 7.4	0.3019
Body temperature (°C)	36.1 ± 1.1	36.0 ± 1.2	36.1 ± 1.2	36.2 ± 1.3	0.1495
PaO2 (mm Hg)	177.8 ± 142.2	217.9 ± 141.7	219.9 ± 144.1	192.3 ± 142.42	0.0003
PaCO2 (mm Hg)	39.8 ± 20.4	40.2 ± 14.3	39.0 ± 10.6	42.1 ± 15.6	0.0098
pH	7.38 ± 0.13	7.38 ± 0.12	7.38 ± 0.11	7.37 ± 0.12	0.4631
Pupil abnormality (N, %)	122 (40.9)	166 (43.6)	207 (43.2)	248 (34.4)	0.0036
Anatomical severity					
ISS Median (IQR)	25.0 (25.0-27.0)	25.0 (17.0-29.0)	25.0 (16.0-27.0)	25.0 (17.0-27.0)	0.0353
Vault fracture (N, %)	144 (48.3)	179 (47.0)	185 (38.6)	304 (42.2)	<0.0001
Basal skull fracture (N, %)	25 (8.4)	48 (12.6)	94 (19.6)	151 (20.9)	<0.0001
Intracranial air (N, %)	10 (3.3)	40 (10.5)	66 (13.8)	108 (15.0)	<0.0001
Traumatic subarachnoid hemorrhage	166 (55.7)	221 (58.0)	330 (68.9)	524 (72.7)	<0.0001
IVH	47 (15.8)	43 (11.3)	65 (13.6)	127 (17.6)	<0.0001
Focal injury (N, %)	256 (44.1)	298 (78.2)	358 (74.7)	539 (74.8)	0.0007
Diffuse injury (N, %)	42 (55.9)	83 (21.8)	121 (25.3)	182 (25.2)	0.0007

Abbreviations: ISS, Injury Severity Score; GCS, Glasgow Coma Scale; IVH, intraventricular hemorrhage. IQR: interquartile range

Table 2 Transition of treatment in elders with traumatic brain injury

Project	1998	2004	2009	2015	*p*-value
Surgical procedure					
Burr hole and irrigation (including HITT) N, (%)	43 (11.8)	40 (10.5)	97 (20.5)	172 (23.9)	<0.0001
Craniotomy N, (%)	102 (34.2)	152 (39.9)	184 (38.4)	236 (32.7)	0.0313
HITT followed by craniotomy N, (%)	6 (2.0)	3 (0.8)	29 (6.1)	12 (1.7)	0.0585
Critical care					
ICP monitoring N, (%)	67 (22.5)	73 (19.2)	116 (24.2)	264 (36.6)	<0.0001
Barbiturate N, (%)	3 (1.0%)	3 (0.8%)	15 (3.1%)	0 (0)	0.1339
Intensive temperature treatment N, (%)	20 (6.7)	101 (26.6)	144 (30.1)	163 (22.6)	<0.0001
Hypothermia N, (%)	20 (6.7)	19 (5.0)	29 (6.1)	11 (1.5)	
Intensive normothermia N, (%)	-	83 (21.8)	115 (24.0)	152 (21.1)	
Aggressive treatment N, (%)	157 (67.0)	226 (58.7)	344 (71.4)	500 (69.3)	<0.0001

Abbreviations: HITT, hematoma irrigation and trepanation therapy; ICP, intracranial pressure.

Table 3 Glasgow Outcome Scale Scores at discharge

Project	1998	2004	2009	2015	*p*-value
Total	290	381	479	721	
Length of hospital stay (days)	27.6 ± 42.8	34.5 ± 51.8	29.0 ± 42.8	26.9 ± 34.2	0.0357
GOS on discharge (N, %)					
GR	22 (7.4)	29 (7.6)	29 (6.1)	47 (6.5)	0.0003
MD	20 (6.7)	38 (10.0)	47 (9.8)	70 (9.7)	
SD	44 (14.8)	79 (20.7)	95 (19.8)	168 (23.3)	
VS	24 (8.1)	50 (13.1)	58 (12.1)	111 (15.8)	
D	188 (62.8)	185 (48.6)	250 (52.2)	322 (44.7)	
Survival rate (N, %)	102 (35.1)	196 (51.4)	229 (47.8)	399 (55.3)	<0.0001
Dependent survivors (N, % in all)	68 (23.2)	129 (33.9)	153 (31.9)	279 (39.1)	<0.0001

Abbreviations: GR, good recovery; MD, moderate disability; SD, severely disabled; VS, vegetative state; D, death.

an increase in focal injuries and a decline in diffuse injuries over time (p = 0.0007).

Transition in Treatment of Geriatric TBI Patients

A comparison of the four project groups showed an increase in trepanations and a decrease in craniotomies (**Table 2**). In P2015, ICP monitoring accounted for 36.6% of all intensive care treatment, while active thermoregulation (cerebral hypothermia, active normothermia) was implemented for 22.6% of all cases. In P2015, the percentage of cases treated aggressively significantly increased, to 69.3%.

Transition in Outcomes of Geriatric TBI Patients

A comparison of the length of hospital stay showed a significant decline over time; the mean length of stay was 26.9 days in P2015 (**Table 3**). A comparison of GOS score on discharge after injury showed a significant reduction in mortality (62.8% in P1998 to 44.7% in P2015; **Table 3**). However, in analysis of the 6-month GOS score, there was a significant increase in the percentage of patients who were severely disabled or in a vegetative state within the dependent survivor group (for whom assistance and nursing is regarded as necessary for daily living): the proportion increased from 11.3% to 19.1% of the whole (p<0.0001; **Table 4**).

Characteristics of the Functionally Poor Outcome Group Among Geriatric TBI Patients

To identify factors associated with functional outcomes of geriatric patients with TBI (**Table 5**), we examined differences between the 6-month good outcome group (good recovery and moderate disability) and poor outcome group (severely disabled, vegetative state, and dead) from P1998 to P2015.

There were significant differences between the good and poor outcome groups in age, body temperature, blood sugar, ISS, GCS score, pupil abnormality, presence of fracture, percentage of traumatic subarachnoid hemorrhage cases, and percentage of IVH cases. When we conducted logistic regression analysis of variables with a p value of <0.1 as independent variables and poor outcome as the dependent variable, age 75 years or older, an ISS

Table 4 Transition of mortality and functional outcomes at 6 months after injury

Project	1998	2004	2009	2015	*p*-value
Total	248	271	389	550	
6-month Glasgow Outcome Scale (N, %)					
GR	18 (7.3)	21 (7.7)	21 (5.4)	52 (9.5)	0.0003
MD	13 (5.2)	18 (6.6)	26 (6.7)	46 (8.4)	
SD	22 (8.9)	22 (8.1)	48 (12.3)	61 (11.1)	
VS	6 (2.4)	23 (8.5)	27 (6.9)	44 (8.0)	
D	189 (76.2)	187 (69.0)	267 (68.6)	347 (63.1)	
Dependent survivors (N, % in all)	28 (11.3)	45 (16.6)	75 (19.3)	105 (19.1)	<0.0001

Abbreviations: GR, good recovery; MD, moderate disability; SD, severely disabled; VS, vegetative state; D, dead.

Table 5 Univariate analysis of good and poor outcomes, 1998-2018

	Good outcome (GR+MD)	Poor outcome (SD+VS+D)	*p*-value
No. of patients	215	1,243	
Age (years)	74.0 ± 6.7	77.3 ± 7.5	<0.0001
Systolic blood pressure (mm Hg)	150.4 ± 31.9	146.0 ± 54.0	0.2401
Heart rate (/min)	86.9 ± 20.6	86.5 ± 30.1	0.8387
Respiratory rate (/min)	20.7 ± 5.8	19.5 ± 8.7	0.0785
Body temperature (°C)	36.4 ± 1.0	36.0 ± 1.4	0.0002
Blood sugar (mg/dL)	155.2 ± 44.7	191.0 ± 73.0	<0.0001
ISS Median (IQR)	23.0 (16.0-25.0)	25.0 (18.0-29.0)	<0.0001
GCS score Median (IQR)	10.0 (6.0-14.0)	6.0 (4.0-8.0)	<0.0001
Pupil abnormality (N, %)	36 (16.7%)	633 (51.0%)	<0.0001
Vault fracture (N, %)	83 (38.6%)	579 (46.5)	0.0002
Basal skull fracture (N, %)	28 (13.6%)	240 (17.6%)	0.0406
Traumatic subarachnoid hemorrhage (N, %)	111 (51.6%)	880 (70.8%)	<0.0001
IVH (N, %)	8 (3.7%)	220 (17.7%)	<0.0001
Focal injury (N, %)	168 (78.1%)	968 (77.9%)	0.2976

Abbreviations: ISS, Injury Severity Score; GCS, Glasgow Coma Scale; IVH, intraventricular hemorrhage; IQR, interquartile range

of ≥25, a GCS score of ≤8, presence of traumatic subarachnoid hemorrhage, and presence of IVH were associated with poor outcomes. Presence of an IVH was the strongest predictive factor (OR 3.79, 95%CI 1.78-8.06, p< 0.0001; **Table 6**).

Discussion

Our analyses showed that less invasive treatments might reduce mortality elders with TBI. However, intensive treatments did not improve functional outcomes. The strongest prognostic factor that impeded aggressive treatment was IVH, and patient age alone was not the strongest prognostic factor. This study is the first to analyze the effectiveness of and trends in treatment for geriatric TBI in a nationwide patient cohort.

Aging of Geriatric TBI is Progressing with "Super-Aging" of Patients

Recent medical advances have led to a steep increase in the super-aged population in Japan. In 2017, the population of elderly Japanese reached its highest point ever, 35,140,000; people aged 65 years and older accounted for 27.7% of the total population (aging rate); thus, almost 1 in 4 people in Japan are elderly[4]. In addition, the population of those aged 90 years and older exceeded 2 million for the first time, highlighting Japan's shift to a super-aging society. While Japan's total population has declined by 210,000 people, the elderly population has increased by 570,000 people. Thus, Japan is predicted to enter the process of long-term population decline associated with the continuously declining birth rate. However, as the baby boom generation enters old age, the elderly population will likely increase even more. By 2035, it is predicted that 1 in 3 Japanese people will be 65 years and older, and this is predicted to increase to 1 in 2.5 people by 2060, when Japan will become an unprecedented aging society[4].

Table 6 Logistic regression analysis of the probability of an unfavorable 6-month outcome

	Odds (95% CI)	*p*-value
Age ≧75	3.27 (2.34–4.57)	<0.0001
GCS score ≦8	2.09 (1.47–2.99)	<0.0001
ISS ≧25	2.46 (1.75–3.45)	<0.0001
Pupil abnormality: Yes	3.11 (2.02–4.79)	<0.0001
Vault fracture: Yes	1.15 (0.81–1.65)	0.432
Skull base fracture: Yes	1.14 (0.69–1.86)	0.608
Traumatic subarachnoid hemorrhage: Yes	1.96 (1.38–2.79)	<0.0001
IVH: Yes	3.79 (1.78–8.06)	<0.0001

Abbreviations: GCS, Glasgow Coma Scale; ISS, Injury Severity Score; IVH, intraventricular hemorrhage.

The elderly population in 2015 (3.3 million) was 1.5 times that of 1998 (2.2 million)[4]. The percentage of geriatric TBIs in Japan is also increasing with the changes in population composition. The present results demonstrate a much greater increase in aging, above what was reported previously[1].

Conversely, it should be noted that although the number of patients with head trauma who were aged 10 to 20 years and 20 to 30 years decreased up to P2009, this trend reversed in 2015, when a slight increase was seen in these age groups. The cause of this change is unclear, but it highlights the importance of being prepared for high-energy trauma caused by sports, traffic injuries, and falls. Continuing to inform young people about the risks of head trauma is indispensable to prevent a decrease in the population of young people able to support the aging society in the future. However, the number of head traumas among elders 75 years of age and older is increasing year-to-year. This increase in elderly-elders with TBI is causing new medical economic problems.

A US report claimed that the frequency of CT and magnetic resonance imaging scans in adults 65 years of age and older is three times that in younger people, and the rate of admission to intensive care unit is four times higher[5]. The annual medical cost per person has increased from US$73,000 to $78,000, and the rehospitalization rate is also higher[6]. The number of head trauma patients 75 years of age and older is also expected to increase in Japan; thus, the importance of medical economics in this field cannot be overlooked.

The Transition in Geriatric TBI Patients

As shown in **Table 1**, the increase in GCS score, particularly in motor score, is noteworthy. The cause is unknown, but the increase in focal injuries associated with aging resulted in an increase in the Talk and Deteriorate group[7], so it is presumed that the GCS score at the initial consultation may have also increased. To confirm this, we found that the proportion of patients in the Talk and Deteriorate group had increased significantly among those in the focal injury group (diffuse injury group 11.3%, focal injury group 24.1%, $p \leq 0.0001$).

Further, while the incidence of vault fracture decreased, the incidences of basilar skull fracture and pneumocephalus, traumatic subarachnoid hemorrhage, and IVH increased. The incidence of traumatic subarachnoid hemorrhage was 72.7% of elderly patients in P2015. It was previously reported that geriatric TBI patients have a specific aging-related pathophysiology before sustaining the injury, including coagulopathy, common use of aspirin and anticoagulants, and increased fragility of blood vessels associated with arteriosclerosis and amyloid angiopathy[8]; thus, the incidence of traumatic subarachnoid hemorrhage in geriatric TBI patients may have increased with the increased age of the affected population.

Reports have suggested that traumatic subarachnoid hemorrhage is a delayed cerebral vascular disorder caused by cerebral vasospasm and that the mortality rate in patients with a traumatic subarachnoid hemorrhage is double that of those without such hemorrhage[1]. This may be an important finding as an outcome predictor in geriatric TBI patients.

Increase of Aggressive Treatment in Geriatric TBI Patients

A general characteristic of head trauma is that outcome worsens with age. Therefore, patient age at the time of injury is listed as an important predictor[9–12]. Several reports concluded that physiological fragility of brain tissue in elders is the cause of poorer outcomes[8,13]. Unfortunately, because brain tissue and cerebral blood vessels are older, patients often do not improve even with aggressive treatment[14]. Additionally, there is no specific evidence-based treatment or guidelines in place for elderly patients that consider pathologies specific to the elderly, which makes it difficult to determine the type of patient for whom aggressive treatment should be used and the extent of such treatment[2].

As neurosurgeons, we are faced with difficult decisions about whether to treat certain patients, and we often treat patients for whom we are concerned about the results our decisions will bring, and experience outcomes that cause us to feel remorse. This study showed that the percentage of geriatric TBI patients undergoing more aggressive forms of treatment is increasing. In particular, the proportion of patients undergoing trepanation increased and the percentage of craniotomy cases decreased, perhaps because doctors considering the physical burdens of such procedures on elderly patients opted for less invasive treatment options.

The number of patients treated with therapeutic hypothermia had rapidly declined, and most treatments are now implemented with normothermia or even active thermoregulation therapy. In particular, the percentage of elderly patients who had cerebral hypothermia treatment did not exceed 1.5% in P2015. This may have been greatly influenced by a multicenter joint study by Clifton et al., which found that, in general, cerebral hypothermia treatment is not effective and, in patients 45 years of age and older, cerebral hypothermia treatment actually increased the risk of poor outcomes[15]. The target disease differed, but the results of a comparative clinical trial (Targeted Temperature Management [TTM] Trial) on normothermia and cerebral hypothermia treatment in post-cardiac arrest syndrome may have also affected this change in treatment practice[16].

In contrast, the ICP monitoring rate was 30% or lower in all three patient groups (P1998, P2004, and P2009) but increased to 36.6% in P2015. Although ICP monitoring is one of the most strongly recommended procedures in the TBI Treatment and Management Guidelines in Japan[17], there are no global reports that provide strong evidence to support this practice. Additionally, because cerebrovascular autoregulation is diminished in elders, as compared with younger age groups[13], future studies of geriatric TBI patients should attempt to determine the preferred treatment threshold for ICP and cerebral perfusion pressure (CPP) in older adults.

A Significant Decrease in Mortality Rate but a Significant Increase in the Rate of Poor Functional Outcomes

The mortality rate of geriatric TBI patients decreased significantly since P1998 because of the aggressive treatment efforts of neurosurgeons. However, the percentage of severely disabled patients significantly increased. Moreover, the percentage of dependent survivors (severely disabled and vegetative state/survivor) has been increasing with time and, in P2015, 19.1% of all cases were dependent survivors. A future issue, in addition to saving patient lives, is to consider how to improve the functional outcome of patients, as well as to dedicate more effort to building a comprehensive treatment strategy that includes neuroprotective therapy, rehabilitation medicine, and regenerative medicine.

Factors Predicting Unfavorable Outcomes in Elders with TBI

The results of our study suggest that aggressive treatment may improve the life prognosis of geriatric TBI patients. However, improvement of functional outcomes should also be a future target. We frequently experience patients in clinical practice for which it is difficult to improve functional outcomes with any kind of aggressive treatment. When a patient becomes bedridden long-term or falls into a vegetative state, it creates enormous psychological and financial burdens for the patient's family. Therefore, it is extremely difficult to determine the extent to which aggressive treatment should be used for certain types of patients, or if it should simply be abandoned. The patient's family is faced with having to decide whether to approve certain treatments in an emergency situation, with limited information available, making the mental burden immeasurable, even beyond that faced by the family of young people with head trauma. It is essential for us to present a certain level of outcome prediction information to patients' families, to help reduce these burdens, and to provide information on outcomes if aggressive treatment is employed.

With this in mind, we used univariate and multivariate analyses to identify factors that predicted poor outcomes in geriatric TBI patients. We examined physiological severity, anatomical severity, and injury findings on hospital arrival from all data of geriatric TBI patients and compared cases with good (good recovery and moderate disability: 215 cases) and poor outcomes (severely disabled, vegetative state, and death: 1,243 cases). The following factors were significantly associated with poor functional outcomes:

Age 75 years and older
ISS ≥25
GCS score ≤8
Traumatic subarachnoid hemorrhage
IVH (extremely strong predictor)

Age 75 years and older and initial GCS score ≤8 were included in previous reports as prognostic determinants for geriatric TBI patients[1], which is consistent with the present results.

While the decision to employ an aggressive treatment strategy should not be determined by a single factor associated with poor outcomes, it is unlikely that patients with a combination of factors will have a good outcome. Providing treatment soon after the patient has sustained the injury is the most important factor for achieving maximum therapeutic benefit with aggressive treatment for head trauma in elderly patients[18], and rapid decision-making is more important for elders than for younger patients. We hope these findings will be of use in future studies.

This study has several limitations. First, this was a retrospective cohort study of JNTDB; thus, treatment indications might have varied among centers, even though all centers recognize and use the Brain Trauma Foundation and Japanese treatment guidelines for TBI[17,19]. Second, this study used data that were prospectively collected over 20 years. We cannot exclude the possibility that general medical standards might have improved during that time.

Conclusions

Aggressive treatment improved life outcomes for geriatric TBI patients, even for patients who received less invasive forms of aggressive treatment and despite the increasing age of the affected patients. In the future, after saving the patient's life, treatment strategies that improve functional outcomes should be investigated. In addition, it is important to be able to make rapid treatment decisions for patients for whom aggressive treatment strategies are not an option and who are thus often classified as the "absolute poor outcome" group.

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