The Influence of Age on the Outcomes of Traumatic Brain Injury: Findings from a Japanese Nationwide Survey (J-ASPECT Study-Traumatic Brain Injury)

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■ BACKGROUND: **The epidemiology of patients with traumatic brain injury (TBI) has changed dramatically over recent decades as a result of rapid advances in aging societies. We assessed the influence of age on outcomes of patients with TBI and sought to identify prognostic factors for in-hospital mortality of TBI among elderly patients.**

■ METHODS: **Using a nationwide database, we analyzed data from 5651 patients with TBI. Univariate analysis was conducted to compare patient demographics, neurologic status on admission, radiologic findings, systemic complication rates, length of hospital stay, in-hospital mortality, and home discharge rates between elderly and nonelderly groups. Multivariable analysis was conducted to determine prognostic factors for in-hospital mortality among elderly patients.**

■ RESULTS: **Overall in-hospital mortality was significantly higher in elderly patients (12.8% vs. 19.3%; $P < 0.001$). In-hospital mortality of elderly patients with mild TBI increased significantly at >7 days after admission, whereas that of elderly patients with moderate or severe TBI was significantly higher immediately after admission. Age (odds ratio [OR], 1.62; $P = 0.024$), male sex (OR, 1.30; $P = 0.004$), Japan Coma Scale score on admission (OR, 5.95, $P < 0.001$), and incidence of acute subdural hematoma (OR, 1.89; $P < 0.001$) were associated with in-hospital mortality in elderly patients with TBI.**

■ CONCLUSIONS: **Elderly patients with TBI showed significantly higher in-hospital mortality. Delayed increases in in-hospital mortality were observed among elderly patients with mild TBI. Level of consciousness on admission was the strongest predictor of in-hospital mortality among elderly patients.**

INTRODUCTION

Traumatic brain injury (TBI) is a major cause of death and disability and has serious impacts on the lives of patients and their families, potentially also leading to enormous economic costs to society.[1,2] According to a report from the Centers for Disease Control and Prevention in the United States, approximately 2.5 million TBI-related emergency department visits, 282,000 TBI-related hospitalizations, and 52,000 TBI-related deaths occurred in that country in 2013.[3] The highest rates of TBI-related emergency department visits, hospitalizations, and

Key words
- Aging
- Hospital mortality
- Prognosis
- Subdural hematoma
- Traumatic brain injury

Abbreviations and Acronyms
ASDH: Acute subdural hematoma
CCI: Charlson Comorbidity Index
CT: Computed tomography
DPC: Diagnosis Procedure Combination
GCS: Glasgow Coma Scale
ICD-10: *International Classification of Diseases, Tenth Revision*
JCS: Japan Coma Scale
OR: Odds ratio
TBI: Traumatic brain injury

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deaths were observed among individuals older than 75 years, with increased fall-related TBI among elderly patients becoming a particularly serious public health problem in the United States.[3] Similarly, in Japan, which has the highest aging population rate in the world, the epidemiologic characteristics of patients with TBI have changed dramatically over the past few decades as a result of the rapid advances in aging society.[4]

Several investigators have described aging as one of the predictors of unfavorable outcomes among patients with TBI.[5-8] However, specific prognostic factors for outcomes of TBI in elderly patients have not been thoroughly discussed. To establish the optimal management for TBI in elderly patients, updated population-based studies of TBI that are suitable for the present population composition and that reflect the epidemiologic aspects of the real world are required.

Recently, using the Japanese Diagnosis Procedure Combination (DPC) database, the J-ASPECT study (Nationwide survey of Acute Stroke care capacity for Proper dEsignation of Comprehensive stroke cenTer in Japan) group carried out a nationwide survey of neurosurgical practices in Japan.[9-12] These nationwide databases provide not only the classic health-related information about individual patients but also information about demographics, infrastructure, and other socioeconomic factors,[13] and researchers have gradually become reliant on the use of big data to create new evidence in TBI.[14-16] Despite several limitations, a nationwide database can provide results from a more general population of patients than a series of randomized control trials, by eliminating potential selection and referral biases.[12] Using the nationwide discharge data obtained from the DPC database, we conducted a retrospective analysis of the influence of age on outcomes for patients with TBI and determined prognostic factors for in-hospital mortality among elderly patients with TBI.

METHODS

The DPC Database

Data for this survey were collected from the Japanese DPC database. The DPC database is a case-mix classification system that was launched in 2002 by the Ministry of Health, Labor and Welfare of Japan, linked to a lump-sum payment system for inpatient care reimbursement.[17] By 2015, an estimated 1580 acute-care hospitals (representing approximately 50% of all acute-care hospital beds) had adopted the DPC data system.[11] Data regarding practices can be obtained from the DPC database, and the medical attendant is responsible for inputting clinical data for each patient. This database contains comprehensive information on all hospitalized patients: the profile of each patient (i.e., age, sex, height, weight, and smoking index); principal diagnoses (coded according to the *International Classification of Diseases and Injuries, Tenth Revision* [ICD-10]); comorbidities on admission (coded according to ICD-10); complications after admission (coded according to ICD-10); level of consciousness on admission; procedures (including surgery, medications, and devices) used during hospitalization; length of stay; discharge status; and medical cost.[17,18]

Data Collection

The current study comprised a cross-sectional survey using the DPC discharge database from institutions participating in the J-ASPECT study. Patients who had been urgently hospitalized for intracranial injury between April 1, 2012 and March 31, 2014 were identified from the de-identified DPC discharge database using the ICD-10 codes related to intracranial injury (S06.0–9). Further investigation was conducted for eligible patients regarding the presence of coexisting intracranial diagnoses. Patients with a scheduled admission were excluded from analysis.

The following data were collected from the DPC database: age and sex; level of consciousness on admission according to the Japan Coma Scale (JCS); whether the patient arrived by ambulance; comorbidities on admission as assessed by the Charlson Comorbidity Index (CCI)[19]; Computed tomography (CT) findings on admission; length of hospital stay; in-hospital mortality; and discharge location. The JCS was originally published in 1974 and remains the most widely used grading scale for assessing impairment of consciousness in Japan (**Table 1**).[9]

Statistical Analysis

We compared clinical characteristics and outcomes between elderly and nonelderly patients with TBI using χ^2 tests for categorical variables and a Student *t* test for continuous variables. Multivariable analysis was undertaken to assess prognostic factors for the in-hospital mortality of elderly patients with TBI. Odds ratios (ORs) were adjusted for age, sex, JCS score on admission, CCI, and the following CT findings on admission: acute epidural hematoma; acute subdural hematoma (ASDH); traumatic subarachnoid hemorrhage; fracture of the skull vault; and fracture of the skull base. All analyses were performed using JMP version 13.2 (SAS Institute Inc., Cary, North Carolina, USA). Values of $P \leq 0.05$ were considered statistically significant.

Ethics Statement

This research was designed by us and approved by the institutional review board at Kyushu University, which waived the requirement for individual informed consent based on the retrospective nature of the study.

RESULTS

Patient Demographics

Data were obtained from 361 institutions participating in the J-ASPECT study. A total of 5651 patients with TBI were identified from the DPC database using ICD-10 codes. Two peaks in age distribution were seen: a small peak at 15–20 years, and a large peak at 75–85 years (**Figure 1**). Mean (± standard deviation) age of the study group was 63.5 ± 22.8 years (median age, 70 years), and 64.7% ($n = 3657$) were male patients.

Characteristics of Patients with TBI by Age Group

To evaluate the clinical characteristics of elderly patients with TBI, we divided the patients into 2 groups by age: nonelderly group (<65 years) and elderly group (≥65 years). The definition of the elderly or geriatric population is arbitrary, but a cutoff age of 65 years has been used in numerous countries and is also the most commonly used value in TBI studies.[20] **Table 2** shows patient characteristics on admission for the 2 age groups. The study cohort comprised 1874 nonelderly patients (33.1%) and 3777 elderly patients (66.9%). The elderly group had a greater

Table 1. Japan Coma Scale for Grading Impairment of Consciousness

Grade	Consciousness Level
1-digit code	The patient is awake without any stimuli, and is:
0	Alert
1	Almost fully conscious
2	Unable to recognize time, place, and person
3	Unable to recall name or date of birth
2-digit code	The patient can be aroused (then reverts to previous state after cessation of stimulation):
10	By easily by being spoken to (or is responsive with purposeful movements, phrases, or words)
20	With a loud voice or shaking of shoulders (or is almost always responsible to very simple words such as yes or no or to movements)
30	Only by repeated mechanical stimuli
3-digit code	The patient cannot be aroused with any forceful mechanical stimuli, and:
100	Responds with movements to avoid the stimulus
200	Responds with slight movements, including decerebrate and decorticate posture
300	Does not respond at all except for changes in respiratory rhythm

R and I are added to the grade to indicate restlessness and incontinence of urine and feces, respectively (e.g., 100-R and 30-RI). Criteria in parentheses are used in patients who cannot open their eyes for any reason.

proportion of males (59.9% vs. 74.4%; $P < 0.001$) and patients with JCS 0-digit or 1-digit code (alert or mildly impaired consciousness, respectively) (47.2% vs. 56.7%; $P < 0.001$), and a smaller proportion of patients brought to the hospital by ambulance (83.7% vs. 78.0%; $P < 0.001$). Mean CCI was significantly higher in the elderly group (1.50 ± 1.61 vs. 4.72 ± 1.30; $P < 0.001$). The incidence of ASDH was significantly higher in the elderly group (43.5% vs. 66.9%; $P < 0.001$). The incidences of acute epidural hematoma, fracture of the skull vault, and fracture of the skull base were significantly higher in the nonelderly group (30.2%, 2.9%, and 10.7%, respectively) than in the elderly group (8.7%, 1.3%, and 3.8%, respectively; $P < 0.001$ each). No significant between-group difference was noted for the incidence of traumatic subarachnoid hemorrhage (23.2% vs. 25.4%; $P = 0.074$).

Systemic Complication Rates and Length of Hospital Stay by Age Group

Table 3 shows systemic complication rates and length of hospital stay for the 2 age groups. The occurrence of pneumonia was significantly higher in the elderly group (8.8% vs. 13.8%; $P < 0.001$). No significant differences between groups were observed for the occurrences of meningitis, sepsis, pulmonary embolism, deep venous thrombosis, or epilepsy (1.5% vs. 1.1%, $P = 0.258$; 2.5% vs. 2.1%, $P = 0.287$; 0.1% vs. 0.2%, $P = 0.376$; 0.7% vs. 0.6%, $P = 0.616$; 11.6% vs. 12.7%, $P = 0.259$, respectively). Median length of hospital stay was significantly longer in the elderly group (29 ± 31.8 vs. 33 ± 35.0; $P < 0.001$).

In-Hospital Mortality and Home Discharge Rates by Age Group

Table 4 shows mortality and home discharge rates for the 2 age groups. In-hospital mortality within 24 hours did not differ

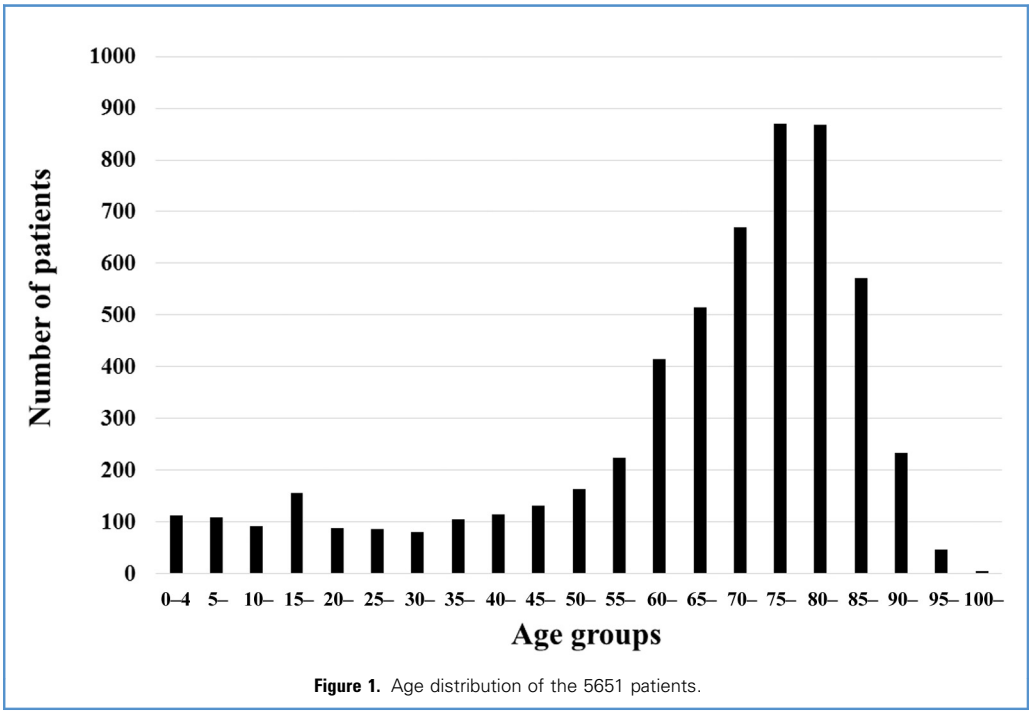

Figure 1. Age distribution of the 5651 patients.

Table 2. Characteristics of Patients with Traumatic Brain Injury by Age Group

	Nonelderly (n = 1874)	Elderly (n = 3777)	*P* Value
Age (years), mean ± standard deviation	37.1 ± 20.4	76.6 ± 7.5	<0.001
Male, n (%)	1394 (74.4)	2263 (59.9)	<0.001
Japan Coma Scale score on admission			<0.001
0-digit or 1-digit code, n (%)	885 (47.2)	2142 (56.7)	
2-digit or 3-digit code, n (%)	989 (52.8)	1635 (43.3)	
Admission source			
Ambulance, n (%)	1569 (83.7)	2947 (78.0)	<0.001
Comorbidities			
Charlson Comorbidity Index, mean ± standard deviation	1.50 ± 1.61	4.72 ± 1.30	<0.001
Computed tomography findings on admission			
Acute subdural hematoma, n (%)	815 (43.5)	2,527 (66.9)	<0.001
Acute epidural hematoma, n (%)	565 (30.2)	330 (8.7)	<0.001
Traumatic subarachnoid hemorrhage, n (%)	435 (23.2)	959 (25.4)	0.074
Fracture of vault of the skull, n (%)	54 (2.9)	50 (1.3)	<0.001
Fracture of base of the skull, n (%)	201 (10.7)	142 (3.8)	<0.001

between nonelderly and elderly groups (3.0% vs. 3.8%; P = 0.138), but in-hospital mortality within 7 days and 30 days and overall in-hospital mortality were significantly higher in the elderly group (7.5% vs. 9.8%, P = 0.004; 11.8% vs. 16.3%, P < 0.001; 12.8% vs. 19.3%, P < 0.001, respectively). Home discharge rates were significantly higher in the nonelderly group (53.7% vs. 34.9%; P < 0.001).

In-Hospital Mortality and Home Discharge Rates by Age Group and JCS Score on Admission

Table 5 shows mortality and home discharge rates by age group and JCS score on admission. In patients with JCS 0-digit or 1-digit code (alert or mildly impaired consciousness, respectively), in-hospital mortality within 24 hours and 7 days after admission did not differ between age groups (0.5% vs. 0.5%, P = 0.956; 2.0% vs. 2.4%, P = 0.512, respectively). However, in-hospital mortality within 30 days and overall in-hospital mortality were significantly higher in the elderly group (3.7% vs. 5.9%, P = 0.016; 4.0% vs. 7.7%, P < 0.001, respectively). In patients with JCS 2-digit or 3-digit code (moderately or severely impaired consciousness, respectively), in-hospital mortality within 24 hours, 7 days, 30 days, and overall was significantly higher in the elderly group (5.3% vs. 8.1%, P = 0.006; 12.3% vs. 19.5%, P < 0.001; 19.0% vs. 29.9%, P < 0.001; 20.6% vs. 34.5%, P < 0.001, respectively). Home discharge rates were significantly higher in the nonelderly group, regardless of JCS score on admission (71.3% vs. 52.3%, P < 0.001 for JCS 0-digit or 1-digit code; 38.1% vs. 12.2%, P < 0.001 for JCS 2-digit or 3-digit code, respectively).

Table 3. Systemic Complication Rates and Length of Hospital Stay by Age Group

	Nonelderly (n = 1874)	Elderly (n = 3777)	*P* Value
Pneumonia, n (%)	165 (8.8)	521 (13.8)	<0.001
Meningitis, n (%)	28 (1.5)	43 (1.1)	0.258
Sepsis, n (%)	47 (2.5)	78 (2.1)	0.287
Pulmonary embolism, n (%)	2 (0.1)	8 (0.2)	0.376
Deep vein thrombosis, n (%)	13 (0.7)	22 (0.6)	0.616
Epilepsy, n (%)	218 (11.6)	479 (12.7)	0.259
Length of hospital stay (days), mean ± standard deviation	29 ± 31.8	33 ± 35.0	<0.001

Predisposing Factors for In-Hospital Mortality Among Elderly Patients with TBI

Table 6 shows multivariable analysis for predisposing factors for in-hospital mortality among elderly patients with TBI. Age (OR, 1.62; P = 0.024), male sex (OR, 1.30; P = 0.004), JCS score on admission (OR, 5.95; P < 0.001), and incidence of ASDH (OR, 1.89; P < 0.001) were associated with in-hospital mortality among elderly patients with TBI. CCI, traumatic subarachnoid hemorrhage, fracture of the skull vault, and fracture of the skull base did not affect the in-hospital mortality of elderly patients.

DISCUSSION

Our data showed that elderly patients with TBI had significantly higher in-hospital mortality and lower home discharge rates than did nonelderly patients. In-hospital mortality of elderly patients with mild TBI was significantly increased from >7 days after admission compared with nonelderly patients, whereas that of

Table 4. In-Hospital Mortality and Home Discharge Rates by Age Group

	Nonelderly (n = 1874), n (%)	Elderly (n = 3777), n (%)	*P* Value
In-hospital mortality within 24 hours	56 (3.0)	142 (3.8)	0.138
In-hospital mortality within 7 days	140 (7.5)	370 (9.8)	0.004
In-hospital mortality within 30 days	221 (11.8)	615 (16.3)	<0.001
Overall in-hospital mortality	239 (12.8)	728 (19.3)	<0.001
Home discharge rates	996 (53.7)	1306 (34.9)	<0.001

elderly patients with moderate to severe TBI was significantly higher immediately after admission. Furthermore, multivariable analysis showed age, male sex, JCS score on admission, and incidence of ASDH as associated with in-hospital mortality among elderly patients with TBI. This nationwide survey analyzed data obtained from not only advanced critical care and emergency centers but also standard acute-care hospitals and includes data related to patients with TBI with various degrees of severity, from mild to moderate and severe. In this regard, the present study provides more generalizable results reflective of the real world of TBI care in Japan than do previous studies.[5,21,22]

The aging of patients with TBI has now become a serious social issue, especially in developed countries.[23] Cadotte et al.[24] reported an approximately 12-year increase in the median age of patients with TBI from 1986 to 2007 in Canada. Our data showed that the mean age of patients with TBI-related hospitalizations in Japan had reached nearly 65 years. Elderly individuals >65 years old accounted for almost 70% of all patients with TBI, and the proportion of elderly patients in this study was higher than in a recent study with a large sample size.[7,8,24] Regarding the age distribution of patients with TBI, the present study showed a tiny peak at 15–20 years and a larger peak at 75–85 years in the age distribution of patients with TBI, and the distribution will have a single peak in the elderly generation. According to a report from the Cabinet Office of Japan, the population >65 years old was 22 million (17.4%) in 2000 and 34 million (26.7%) in 2015. The rapid advancement in the aging of society in recent decades may contribute to these dynamic changes in the demographic structure of patients with TBI in Japan.

Our study showed that elderly patients with TBI showed several significant differences in clinical characteristics compared with younger patients. Elderly patients with TBI showed significantly worse outcomes compared with younger patients despite the level of consciousness on admission being better. Mortality within 24 hours did not differ between age groups, but mortality >24 hours after admission was significantly higher in the elderly group. Furthermore, the time course of mortality among elderly patients depended on the patient's level of consciousness on admission. In patients with JCS 0-digit or 1-digit code, elderly patients had significantly higher in-hospital mortality compared with younger patients at >7 days after admission. In contrast, in patients with JCS 2-digit or 3-digit codes, elderly patients had higher in-hospital mortality immediately after admission. This delayed deterioration in elderly patients with mild TBI has been described previously[25] and appears often induced by delayed hyperemia, hyperperfusion, or expansion of hematoma or cerebral edema.[4] Cerebrovascular autoregulation declines with increasing age and irreversible damage might occur if adequate control of intracranial pressure is not achieved early in the postinjury period.[26] Another possible explanation for this phenomenon is mortality associated with comorbidities. Our data showed that elderly patients showed a significantly higher mean CCI on admission compared with younger patients, and rates of pneumonia onset after admission were also higher in elderly patients. Aggravation of comorbidities may increase the in-hospital mortality of elderly patients with mild TBI at >7 days after admission. Few studies have focused on the criteria for hospitalization or appropriate observation period for elderly patients with TBI, and establishment of optimal management

Table 5. In-Hospital Mortality and Home Discharge Rates by Age Group and Japan Coma Scale Score on Admission

Japan Coma Scale 0-Digit or 1-Digit Code	Nonelderly (n = 885), n (%)	Elderly (n = 2142), n (%)	*P* Value
In-hospital mortality within 24 hours	4 (0.5)	10 (0.5)	0.956
In-hospital mortality within 7 days	18 (2.0)	52 (2.4)	0.512
In-hospital mortality within 30 days	33 (3.7)	126 (5.9)	0.016
Overall in-hospital mortality	35 (4.0)	164 (7.7)	<0.001
Home discharge rates	622 (71.3)	1,109 (52.3)	<0.001
Japan Coma Scale 2-Digit or 3-Digit Code	**Nonelderly (n = 989), n (%)**	**Elderly (n = 1635), n (%)**	***P* Value**
In-hospital mortality within 24 hours	52 (5.3)	132 (8.1)	0.006
In-hospital mortality within 7 days	122 (12.3)	318 (19.5)	<0.001
In-hospital mortality within 30 days	188 (19.0)	489 (29.9)	<0.001
Overall in-hospital mortality	204 (20.6)	564 (34.5)	<0.001
Home discharge rates	374 (38.1)	197 (12.2)	<0.001

Table 6. Predisposing Factors for In-Hospital Mortality Among Elderly Patients with Traumatic Brain Injury

	Odds Ratio	95% Confidence Interval	*P* Value
Age	1.62	1.06—2.46	0.024
Male sex	1.30	1.09—1.56	0.004
Japan Coma Scale score on admission*	5.95	4.89—7.23	<0.001
Charlson Comorbidity Index	1.13	0.49—2.59	0.775
Acute epidural hematoma	0.93	0.65—1.34	0.701
Acute subdural hematoma	1.89	1.48—2.41	<0.001
Traumatic subarachnoid hemorrhage	1.12	0.89—1.41	0.339
Fracture of vault of the skull	1.09	0.50—2.41	0.822
Fracture of base of the skull	1.37	0.89—2.12	0.154

*Japan Coma Scale score 2-digit or 3-digit code versus Japan Coma Scale score 0-digit or 1-digit code.

strategies for TBI in elderly patients is thus an urgent and important issue.[4] Our results suggest that careful observation and repeated neurologic imaging should be recommended for certain periods, even in mild TBI. Furthermore, JCS score on admission seemed to have a significant impact on home discharge rates for elderly patients. Patients who are not discharged to home are presumed to be transported to inpatient rehabilitation services, nursing homes, or long-term care facilities, which may lead to increasing medical costs. There is a strong need for the establishment of systematic prevention and treatment for elderly patients with TBI to suppress the expansion of medical costs and social losses.

Several factors have been described as prognostic factors for unfavorable outcomes among patients with TBI, including age, female sex, Glasgow Coma Scale (GCS), pupil reactivity, presence of major extracranial injury, and CT abnormalities such as midline shift or obliteration of the third ventricle.[27-29] In the present study, multivariable analysis showed that JCS score on admission was the strongest prognostic factor for in-hospital mortality among elderly patients with TBI. The JCS is widely used for the assessment of impaired consciousness of patients in Japan,[9] and the Japanese DPC database adopted the JCS for assessing the level of consciousness in patients. The J-ASPECT study group used JCS scores in recent Japanese DPC database studies and created new evidence in clinical practices.[9-12] Although only a few studies related to traumatic care have used the JCS score for assessing impairment of consciousness,[30] JCS scores and GCS scores have been described as showing a good correlation in patients with TBI.[31] JCS offers outstanding merits in simplicity and applicability and is particularly valuable in emergency settings.[32]

Our data showed male sex as an independent prognostic factor for in-hospital mortality among elderly patients with TBI. Only a small percentage of the published literature classified outcomes of patients with TBI by sex, and the impact of gender on outcomes for patients with TBI remains controversial.[28,33-35] Berry et al.[33] described female patients with TBI older than 45 years as showing better outcomes compared with their male counterparts. Similarly, Brazinova et al.[34] described more favorable outcomes in females than in males among patients with TBI with low GCS score. On the other hand, a meta-analysis related to gender differences in outcomes of TBI[28] described female patients as showing worse outcomes compared with male patients. However, most of the literature reviewed in the analysis showed a lower proportion of elderly patients compared with the current study, a fact that must be taken into consideration. Farin et al.[35] explained the worse outcomes in female patients ≤50 years old with severe TBI as caused by the influence of posttraumatic brain swelling and intracranial hypertension induced by increased levels of gonadal hormone, and this phenomenon was not observed among female patients >50 years old. Although there is room for further examination, our results suggest a propensity in that more female patients have better outcomes as age increases.

The incidence of ASDH was also assumed to represent a prognostic factor for unfavorable outcomes among elderly patients in the present study. This result has been supported by the literature.[36,37] The most common mechanism for ASDH in elderly patients has been reported to be falls, and the initial injury was often less severe compared with younger patients with ASDH.[36] However, age-related brain atrophy contributes to stretching of the bridging veins and development of subdural hematoma, resulting in a larger average volume of subdural hematoma compared with younger patients.[36] The regenerative capacity of the aging brain may also be attributed to the poor outcomes of elderly patients with ASDH.[36]

Our study had several imitations. First, the DPC database lacks several important types of data for patients with TBI such as mechanism of injury, injury severity score, and detailed clinical findings of patients (e.g., presence or absence of extracranial injury, vital signs, pupil reactivity, hemodynamics, respiratory status, or intracranial pressure). Furthermore, the DPC database contains information collected only during hospitalization, so we were unable to assess the long-term outcomes of patients. These missing data were unmeasured variables for the present study and clearly may have affected patient outcomes. From this perspective, there is a need for further investigations combining the DPC database with other data, including radiologic and laboratory findings or patient progress after discharge. Second, in the DPC database system, the attending physician is responsible for inputting all clinical data for each patient, so there is a potential risk of inaccurate data.

Despite several limitations, up-to-date information about health care has been accumulated in the DPC database annually, and nationwide studies using the DPC database could provide new evidence for clinical practices from a general population reflecting real-world conditions.

CONCLUSIONS

This is the largest Japan-wide study to investigate the influence of age on the clinical outcomes of patients with TBI. Our data showed dynamic changes in the demographic structure of patients with TBI, triggered by the rapid advance of aging society in Japan. Elderly patients with TBI had significantly higher in-hospital mortality and lower home discharge rates, despite the level of consciousness on admission being better, and delayed increases in mortality were observed among elderly patients with mild TBI. Level of consciousness on admission was the strongest predictor of in-hospital mortality among elderly patients with TBI.

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Supplementary Table 1. Continued

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Yokohama City University Medical Center	Katsumi Sakata
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Hamamatsu Medical Center	Teiji Nakayama
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Continues

Supplementary Table 1. Continued

Hospitals	Responsible Persons
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Gifu Municipal Hospital	Tetsuya Tanigawara
Gifu University Hospital	Toru Iwama
Gifu Prefectural Tajimi Hospital	Junki Ito
Toki General Hospital	Shinji Noda
Saku Central Hospital	Kazuyuki Kouno
Aizawa Hospital	Kazuo Kitazawa
Nagano Municipal Hospital	Yoshikazu Kusano Toshiki Takemae
Nagano Prefectural Suzaka Hospital	
Shinonoi General Hospital	Masanobu Hokama
Suwa Central Hospital	Hiroki Sato Yoshihisa Nishiyama
Seguchi Neuro Surgery Hospital	Tatsuya Seguchi
Iida Municipal Hospital	Sumio Kobayashi Yoshihiko Inui, Youji Oohigashi
Showa Inan General Hospital	Shinsuke Muraoka
Japanese Red Cross Society Azumino Hospital	Masaki Miyatake
Azumi General Hospital	Kensuke Hayashida Nakagawa Shinichi
Nagano Prefectural Kiso Hospital	Atsushi Inoue
Nho Shinshu Ueda Medical Center	Keiichi Sakai
Shimane University Hospital	Shuhei Yamaguchi
Shimane Prefectural Central Hospital	Tatsuya Mizoue Fusao Ikawa
Yasugi Municipal Hospital	Gen Ishida Hideki Irie
National Hospital Organization Hamada Medical Center	Takato Kagawa
National Hospital Organization Okayama Medical Center	Yoichiro Namba
Okayama Kyokuto Hospital	Hiroyuki Nakashima
Okayama University Hospital	Isao Date Koji Abe
Kawasaki Medical School Hospital	Masaaki Uno
Kurashiki Central Hospital	Masaki Chin Sen Yamagata
Kurashiki-Heisei Hospital	Hidemiti Sasayama Soitiro Takao
Tsuyama Chuo Hospital	Hideyuki Yoshida Kouji Muneda
Okayama Kyoritsu General Hospital	
Kasaoka Daiichi Hospital	Akira Watanebe
Saiseikai Yamaguchi General Hospital	Syouichi Katou
Japanese Red Cross Yamaguchi Hospital	Yasuhiro Hamada
Department of Neurosurgery, Yamaguchi University School of Medicine	Michiyasu Suzuki
Ube Industries Central Hospital	Takafumi Nishizaki
Kanmon Medical Center	Katsuhiro Yamashita

All contributors were involved in collection of data.

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Supplementary Table 1. Continued

Hospitals	Responsible Persons
Shimonoseki City Hospital	Takaharu Nakamura Ryuji Nakamura
Suiseikai Kajikawa Hospital	Shinichi Wakabayashi
Hiroshima University Hospital	Takahito Okazaki, Kaoru Kurisu, Masayasu Matsumoto,
Hiroshima Prefectural Hospital	Atsushi Tominaga Katsuzo Kiya
Araki Neurosurgical Hospital	Masaaki Shibukawa Syuichi Oki
Itsukaichi Memorial Hospital	
Mazda Hospital	Toshinori Nakahara
Chugoku Rosai Hospital	Shinji Okita
National Hospital Organization Kure Medical Center	Tuyosi Torii
Rijinkai Medical Foundation Socio-Medical Corporation Kohsei General Hospital	Minoru Nakagawa Kenjirou Fujiwara
Mitsugi General Hospital	Takashi Matsuoka Syuuhei Nishimura
Miyoshi Central Hospital	Osamu Hamasaki Naoyuki Isobe
Tokushima University	Junichiro Satomi Shinji Nagahiro
Tokushima Prefecture Naruto Hospital	Masahito Agawa
Tokushima Prefectural Kaifu Hospital	Hirofumi Oka
Kansai Medical University Hirakata Hospital	Kunikazu Yoshimura
Hakodate Central General Hospital	Tsutomu Kato
Hokusyoukai Otaru Chuo Hospital	Nobuaki Kobayasi Satoshi Minoshima
Sapporo Medical University Hospital	Nobuhiro Mikuni
Sapporo Teishinkai Hospital	Rokuya Tanikawa
JA Akita Kouseiren Oomagari Kousei Medical Center	Jyunkou Sasaki
Noshiro Kosei Medical Center	Yasunari Otawara
Tohoku University Hospital	Teiji Tominaga
Aomori Prefectural Central Hospital	Tatsuya Sasaki
Social Welfare Organization Saiseikai Imperial Gift Foundation Inc.Yamagata Saisei Hospital	Sunao Takemura
Ohta Nishinouchi Hospital	Masahisa Kawakami
Tokyo Metropolitan Childrens Medical Center	Satoshi Ihara
Mito Kyodo General Hospital	Yasushi Shibata
Chiba Rosai Hospital	Takashi Saegusa
Chiba Cancer Center	Toshihiko Iuchi
Chiba Children's Hospital	Chiaki Ito
Juntendo Tokyo Koto Geriatric Medical Center	Osamu Okuda
School of Medicine Keio University	Kazunari Yoshida
Tokyo Dental College Ichikawa General Hospital	Sadao Suga Masateru Katayama
Ebina General Hospital	
Tokyo Metropolitan Health and Medical Treatment Corporation Ohkubo Hospital	Oikawa Akihiro
Itabashi Chuo Medical Center	Naohisa Miura
Tokyo Metropolitan Tama Medical Center	Takahiro Ota
Kitasato University School of Medicine	Toshihiro Kumabe
Yokohama Asahi Chuo General Hospital	Sachio Suzuki

Continues

Supplementary Table 1. Continued

Hospitals	Responsible Persons
Yamagata Prefectural Central Hospital	Takashi Kumagai
Japanese Red Cross Akita Hospital	Keiichi Nishimaki
Shinshu University Hospital	Kazuhiro Hongo
Nagano Children's Hospital	Hiroaki Shigeta
Chubu Rosai Hospital	Kazuyoshi Hattori
Kamiiida Daiichi General Hospital	Yoichi Uozumi
Nagoya Central Hospital	Norimoto Nakahara
Nagoya City East Medical Center	Nobukazu Hashimoto
Daiyukai General Hospital	Shinichi Shirakami Shu Imai
Seikeikai Hospital	Yoshinari Okumura
Higashiosaka City General Hospital	Ryo Tamaki Kazuhiro Yokoyama
Kyoto University Graduate School of Medicine	Susumu Miyamoto
Kishiwada City Hospital	Kenji Hashimoto
Rakuwakai Otowa Hospital	Kazuo Yamamoto
First Towakai Hospital	Tsugumichi Ichioka
Ishikiriseiki Hospital	Tsuyoshi Inoue
Osaka Medical Center for Cancer and Cardiovascular Diseases	Manabu Kinoshita
Rinku General Medical Center	
Akashi City Hospital	Minoru Saitoh
Hyogo Prefectural Kakogawa Medical Center	Hideo Aihara
Tokushima Red Cross Hospital	Hajimu Miyake
National Hospital Organization, Iwakuni Clinical Center	Kotaro Ogihara Tukasa Nishiura
Hiroshima City Hiroshima Citizens Hospital	Shigeki Nishino
Okayama Saiseikai General Hospital	Yasuyuki Miyoshi
Fukuyama City Hospital	Tadashi Arisawa
Onomichi Municipal Hospital	Shigeru Daido Shoji Tsuchimoto
Kaneda Hospital	Kimihisa Kinoshita
Higashihiroshima Medical Center	Kiyoshi Yuki Keisuke Migita
Tottori Municipal Hospital	Keiichi Akatsuka
Shuto General Hospital	Hirosuke Fujisawa
Harasanshin Hospital	Tadahisa Shono
Japanese Red Cross Fukuoka Hospital	Hitoshi Tsugu
Hakujyuji Hospital	Shuji Hayashi
School of Medicine, Saga University	Tatsuya Abe Toshio Matsushima
St. Mary's Hospital	Susumu Nakashima
Tobata Kyoritsu Hospital	Takehisa Tuji
Koseiren Tsurumi Hospital	Akihiko Kaga
Sanseikai Kanemaru Neurosurgery Hospital	Reizou Kanemaru
Atsuchi Neurosurgical Hospital	Koji Takasaki

All contributors were involved in collection of data.

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Supplementary Table 1. Continued

Hospitals	Responsible Persons
Kagoshima Medical Center	Junichi Imamura
Okinawa Red Cross Hospital	Masahiro Noha
Asahi General Hospital	Saburo Watanabe
Kobe City Medical Center General Hospital	Nobuyuki Sakai
Yoshida Hospital. Cerebrovascular Research Institute	Yasuhisa Yoshida Hiroaki Minami
Teishinkai Hospital	Tomoyoshi Okumura
Southern Tohoku General Hospital	Shinjitsu Nishimura
Tokyo General Hospital	Shinichi Numazawa
Fukuoka University Chikushi Hospital	Kiyoshi Kazekawa Masanori Tsutsumi
Fukuoka Wajiro Hospital	Kouzou Fukuyama
Kansai Electric Power Hospital	Yasuhiro Fujimoto

All contributors were involved in collection of data.