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Epidemiological Trends and Rehabilitation Utilization of Traumatic Brain Injury in Korea (2008–2018)

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HIGHLIGHTS

- Trends of traumatic brain injury (TBI) vary based on insurance types and age groups.
- TBI-related medical usage and costs differed between insurance types.
- For oriental medicine, TBI-relates medical usage sharply increased.

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ABSTRACT

This study aimed to estimate the trend of traumatic brain injuries (TBIs) and TBI-related medical usage in Korea. Patients first diagnosed with disease codes of TBIs were included. We calculated the crude incidence and age-adjusted incidence, as well as medical cost, length of stay (LOS), clinic visits, and the number of specialized rehabilitation therapy for 1 year. Patients first diagnosed as TBI was higher in national health insurance (NH-I) than in automobile insurance (AUTO-I). In contrast with the gradual decrease of the crude incidence, total medical costs both in NH-I and AUTO-I were generally and steadily increased. For oriental medicine, total medical costs dramatically increased in both inpatient and outpatient. LOS, clinic visits, and the number of specialized rehabilitation therapy were higher in AUTO-I than in NH-I. The most frequent age groups in NH-I were the young (0–9) and old (70 or over), whereas in AUTO-I, the working age group was prominent. Our results show differences in the incidence of TBI and medical usage between NH-I and AUTO-I, which could be associated with the policy for strengthening health insurance coverage, automobile-related regulations to prevent accidents and injuries, as well as rapid changes in the structure of the population in Korea.

Keywords: Traumatic Brain Injury; Epidemiology; Cost of Illness; Rehabilitation

INTRODUCTION

Traumatic brain injuries (TBIs) lead to death or serious physical and mental disabilities, having profound impact on families and society. Approximately 69 million new cases of TBI are reported worldwide each year [1]. Approximately 1.7 million TBIs occur annually in the United States, resulting in approximately 275,000 hospitalizations, 52,000 deaths, and direct and indirect costs of approximately $76 billion per year [2,3]. In 2012, the pooled age-adjusted discharge from 24 countries was 287.2 and the pooled age-adjusted mortality was 11.7 in the European Union [4]. According to a study based on the National Health Insurance Service (NHIS) data in Korea, more than 250,000 cases of TBI occur annually because of falls, sports activities, and various causes other than road traffic accident (RTA) [5]. Falls and RTAs are the most common causes of TBI worldwide [6,7]. It is noteworthy that the NHIS

data in Korea does not include any information about TBI caused by RTA. Although it is important to consider national health insurance (NH-I) and automobile insurance (AUTO-I) together in determining the incidence rate of TBIs in Korea; however, the 2 databases are separate. In addition, it is expected that the epidemiological trends of TBIs will change as various automobile-related regulations are strengthened to prevent automobile accidents and injuries, as well as rapid changes in the demographic structure of Korea due to its aging population. This study aimed to estimate the trend of TBIs and TBI-related medical usage in Korea using data from both NHIS and Health Insurance Review and Assessment (HIRA).

MATERIALS AND METHODS

Data source and population

This population-based retrospective cohort study used data on approved claims from NHIS and HIRA. The NHIS and HIRA databases consist of approximately 98% claims from the Korean population and include information on the beneficiaries, including age, sex, and healthcare utilization such as diagnosis, tests, prescriptions, and costs. The HIRA has been entrusted with automobile insurance reviews on medical payments since July 2013, and the data can be used to track TBIs caused by RTAs. In this study, we used NHIS data from January 1, 2008 to December 31, 2017, and HIRA data from January 1, 2014, to December 31, 2018.

A widely accepted definition for TBI is "acute brain injury resulting from mechanical energy to the head from external physical forces," according to the criteria defined by the World Health Organization in 2004 [8]. The NHIS and HIRA use the Korean Classification of Diseases based on the International Classification of Diseases 10th version but modified to accommodate the circumstances in Korea [9]. To extract data on TBI patients, the following codes were applied consistently in this study: concussion (S06.0), cranial fractures (S02.0, S02.1, S02.7, S02.8, and S02.9), and intracranial injuries (S06.1–S06.9).

Medical service utilization related to TBI

To analyze the utilization of medical service due to TBI, patient data were analyzed for 1 year from the time of the first TBI-related claim. Data on total medical cost, length of stay (LOS), number of clinic visits, and number of specialized rehabilitation therapy were collected.

The total medical costs were calculated separately for inpatient and outpatient services. Claim codes for specialized rehabilitation therapy for patients with moderate and severe TBI included MM105 (physical therapy for people with central nervous system disorders), MM113 (occupational therapy), and MM114 (activities of daily living training). To distinguish patients with moderate and severe TBI, patients with only a disease code for concussion (S06.0) in their diagnosis were excluded. Finally, utilization of medicine and oriental medicine was calculated separately; however, such data were not available from NH-I.

Statistical analysis

The crude incidence and age-adjusted incidence per 100,000 persons were calculated to identify the trends in TBI incidence. First, the crude incidence was calculated by dividing the number of TBI patients by the mid-year population of the corresponding year and then multiplying by 100,000. The mid-year population was the number of individuals counted in the middle of the year (July 1). Second, considering the rapid change in the population structure of Korea, we obtained age-adjusted incidence to accurately determine the changes

in the epidemiological trend of TBI. The age-adjusted incidence negated the effect of age structure on the incidence to compare the incidence among groups with different population structures. In this study, the age-adjusted incidence was calculated by correcting the incidence by the age-specific mid-year population of Korea and by the world standardized population for international comparison.

RESULTS

Trends of TBI incidence

Table 1 and **Fig. 1** show the trend of TBI NH-I and AUTO-I, respectively and the number of new TBI cases and age-adjusted incidence in Korea. The average number of TBI patients was 270,000 from NH-I and 190,000 from AUTO-I. Estimates of TBI patients in AUTO-I from 2008 to 2013 applied the inverse rate of change of traffic accident patients to the number of TBI patients of AUTO-I in 2018. New cases of TBIs were found to be higher in NH-I data than in AUTO-I, but a decreasing trend was found in both.

Fig. 2 shows the crude incidence by age group during the study period, showing a clear difference according to insurance type. In particular, there was a difference in the crude incidence in the group under 10 years of age. In addition, the incidence rate in the 0–9 group was higher in NH-I than in AUTO-I (1,211 cases vs. 214 cases, respectively). The incidence in NH-I decreased sharply to 512.6, 399.2, 359.6, and 420.7 cases for the age groups 10–19, 20–29, 30–39, and 40–49 years, respectively, and increased again to 538.3, 566.9, and 704.9 cases for the age groups 50–59, 60–69, and 70 years or over, respectively. A different pattern
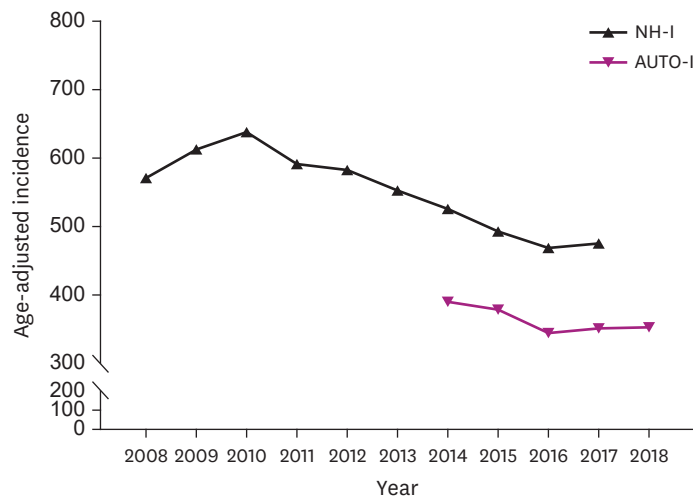

Fig. 1. Trends in age-adjusted incidence of traumatic brain injury by insurance type.
NH-I, national health insurance; AUTO-I, automobile insurance.

Table 1. Trends of TBI cases (2008–2018) by insurance type

Type of insurance	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NH-I	278,228	299,561	313,455	291,208	290,075	277,250	266,232	252,233	241,957	247,989	-
AUTO-I	206,263*	220,205*	214,475*	207,741*	209,672*	200,025*	207,325	202,176	186,147	190,737	196,572
Total	484,491	519,766	527,930	498,949	499,747	477,275	473,557	454,409	428,104	438,726	-

TBI, traumatic brain injury; NH-I, national health insurance; AUTO-I, automobile insurance.
*Estimate of TBI patients due to automobile accidents based on the number of injuries compared to annual traffic accidents in Korea.
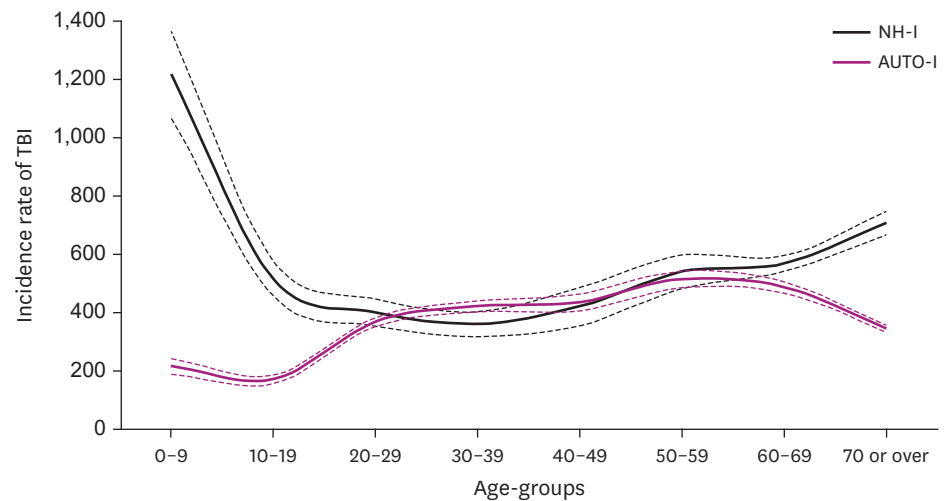
Fig. 2. Trends in the crude incidence rate of TBI (NH-I, 2008-2017; AUTO-I, 2014-2018) by age group and insurance type.
TBI, traumatic brain injury; NH-I, national health insurance; AUTO-I, automobile insurance.

was observed between AUTO-I and NH-I. A rapid increase in incidences was observed in the 20–29 age group after showing the lowest incidence in 10–19 age group (170.7 cases), and the highest incidence was observed in the 50–59 years group (368.2 cases in 20–29, 420.1 cases in 30–39, 434.6 cases in 40–49, 513.5 cases in 50–59 age groups). The incidence rate subsequently decreased in the 60–69 and 70 or over age groups (485.8 cases and 345.1 cases, respectively).

Total medical care cost related to TBIs

Table 2 shows the total medical expenses by type of insurances and medical services. The medical costs for oriental medicine were calculated separately for AUTO-I. Except for the cost for oriental medicine, medical costs in AUTO-I remained stable at an average of $201 million. By contrast, the medical costs for TBI in NH-I have been growing steadily until it reached approximately $247 million in 2017. Although the number of patients was higher in NH-I than in AUTO-I, total medical costs were higher in AUTO-I than in NH-I. The costs of inpatient care in NH-I were dramatically increased from $151 million in 2014 to $247 million

Table 2. Total cost of medical care related to traumatic brain injuries (2014–2017)

Description	Cost (USD)			
	2014	2015	2016	2017
NH-I (medicine)				
Inpatient	151,617,904	168,339,709	187,466,251	247,514,225
Outpatient	36,886,031	36,835,149	31,512,170	35,489,117
AUTO-I (medicine)				
Inpatient	177,599,656	181,285,408	178,882,698	185,517,293
Outpatient	22,302,085	22,469,382	19,090,440	20,413,081
AUTO-I (oriental medicine)				
Inpatient	5,688,425	8,343,376	8,217,649	10,200,293
Outpatient	2,450,254	3,587,259	4,159,159	5,376,187
Annual increase of health insurance reimbursement rate (%)				
Medicine clinic	-	2.15	2.24	2.96
Medicine hospital	-	1.74	1.43	1.83
Oriental clinic, hospital	-	3.05	2.96	3.13

NH-I, national health insurance, AUTO-I, automobile insurance.
1 KRW = 0.000886 USD.

Table 3. Total cost and cost per capita per year of medical care grouped by type of injuries in national health insurance (2014–2017)

Type of TBI	Cost (USD)*			
	2014	2015	2016	2017
Concussion				
Inpatient	37,583,074 (1,165)	38,327,808 (1,251)	42,380,335 (1,019)	48,556,436 (1,143)
Outpatient	28,917,139 (143)	29,256,267 (151)	24,789,113 (144)	27,605,052 (150)
Cranial fracture				
Inpatient	24,663,603 (4,287)	27,193,888 (4,717)	29,444,636 (4,991)	39,184,446 (6,368)
Outpatient	2,052,431 (252)	2,069,776 (267)	1,829,328 (253)	2,094,504 (260)
Intracranial injury				
Inpatient	89,415,804 (6,058)	102,867,506 (6,879)	115,696,396 (6,913)	159,846,114 (8,455)
Outpatient	5,927,305 (208)	5,519,936 (218)	4,902,993 (205)	5,799,996 (217)

TBI, traumatic brain injury.
1 KRW = 0.000886 USD.
*Total cost (cost per capita per year).

in 2017. However, there was no change in the outpatient medical costs in both insurances. In contrast, a clear increasing trend of medical costs for oriental medicine was confirmed in AUTO-I. Inpatient and outpatient medical expenses each doubled during the same period (inpatient: $56 million in 2014, $102 million in 2017; outpatient: $24 million in 2014, $53 million in 2017).

Table 3 shows the total medical costs sorted according to the type of TBI in NH-I. Costs of treating intracranial injury were the highest among all the medical costs of TBI. Costs for inpatient service have increased gradually and continuously in all TBI types.

Medical cost per capita per year related to TBI

Table 4 shows the medical care costs of patients per capita per year. As a result of identifying medical costs, we found that the cost of inpatient medical services in NH-I was higher than that in AUTO-I. In addition, the inpatient medical costs in both insurances increased over time. On the other hand, in the case of outpatient medical care, expenses were higher in AUTO-I than in NH-I. Costs for oriental medicine in AUTO-I were found to continually increase in both inpatient and outpatient services.

We also found that patient costs per capita per year for inpatient service were $1,143 for concussion, $6,368 for cranial fracture, and $8,455 for intracranial injury (**Table 3**). While the medical costs for outpatient service did not show large changes, the costs of inpatient service for cranial fracture and intracranial fracture have increased gradually.

Table 4. Cost per capita per year of medical care related to traumatic brain injury, by insurance type

Description	Cost (USD)			
	2014	2015	2016	2017
NH-I (medicine)				
Inpatient	2,873	3,278	2,919	3,665
Outpatient	155	162	155	162
AUTO-I (medicine)				
Inpatient	1,695	1,799	1,917	2,015
Outpatient	171	178	168	172
AUTO-I (oriental medicine)				
Inpatient	785	827	851	904
Outpatient	447	443	465	471

NH-I, national health insurance, AUTO-I, automobile insurance.
1 KRW = 0.000886 USD.

Table 5. Average length of stay (days, inpatient) and number of visits (outpatient) related to traumatic brain injury

Type of insurance	Setting	2014	2015	2016	2017
NH-I (medicine)	Inpatient	11.7	11.8	9.3	9.2
	Outpatient	1.6	1.6	1.6	1.6
AUTO-I (medicine)	Inpatient	19.5	19.2	18.5	18.6
	Outpatient	3.8	3.7	3.7	3.6
AUTO-I (oriental medicine)	Inpatient	11.0	10.7	11.1	11.9
	Outpatient	13.4	11.6	14.0	16.7

NH-I, national health insurance, AUTO-I, automobile insurance.

Table 6. Average LOS grouped by type of injuries in national health insurance (2014–2017)

Type of TBI	LOS (days)			
	2014	2015	2016	2017
Concussion	10.3	10.7	7.3	8.0
Cranial fracture	10.1	11.2	8.4	9.7
Intracranial injury	23.5	26.7	23.7	39.7

LOS, length of stay; TBI, traumatic brain injury.

Table 7. Average number of sessions per patient for specialized rehabilitation therapy

Type of insurance database	Average number of sessions per person			
	2014	2015	2016	2017
National health insurance	13.3	12.8	12.0	11.8
Automobile insurance	30.3	35.1	36.7	39.5

Medical care utilization related to TBI

Table 5 shows the average LOS of inpatient care and clinic visits of outpatient service according to insurance type. Regarding the use of medical institutions, the average LOS was longer for those using inpatient medical services than for those using clinic visits, and both average LOS and the average number of clinic visits were higher in AUTO-I than in NH-I. While the average LOS in NH-I was approximately 10.5 days, the average LOS in AUTO-I was 19.0 days. Moreover, the average number of clinic visits was 1.6 in NH-I and 3.7 in AUTO-I. On the other hand, when oriental medicine was used under AUTO-I, outpatient medical services were used longer than inpatient medical services. Especially, the average number of clinic visits in AUTO-I was 13.9, which was approximately 9 times more than NH-I and approximately 4 times more than AUTO-I.

Table 6 shows the average LOS of impatient care in NH-I, grouped by TBI. We found that the average LOS for intracranial injury was the highest. In contrast, the average LOS for concussion and cranial fracture was about 10 days and showed a gradual decrease.

Specialized rehabilitation therapy related to TBI

Table 7 shows the average number of sessions for specialized rehabilitation therapy per patient, in which a marked difference was observed according to insurance type. In NH-I, the average number of sessions slightly decreased from 13.3 in 2014 to 11.8 in 2017, but the data in AUTO-I showed an increase from 30.3 in 2014 to 39.5 in 2017.

DISCUSSION

This novel study used data from the NHIS and HIRA repositories to estimate the incidence of TBIs and related medical care utilization in Korea. The main findings of this study are as

follows: 1) approximately 480,000 new TBI cases annually, 2) high medical costs per capita per year of NH-I, and 3) increasing trend of medical costs in oriental medicine.

In the NH-I, the highest incidence was found in the 0–9 age group, but low incidences were observed in the 10–19, 20–29, 30–39, and 40–49 age groups. Meanwhile, the incidences of TBI in the NH-I showed a gradual increase starting from the 50s to the 60s and 70s and over age groups. Despite the aging trend of the population, the overall incidence of TBI in NH-I has decreased. Although the decline in the under-teens group, in particular, was remarkable (1,274.3 in 2008, 998.4 in 2017), that in the elderly population, defined as those in their 70s or older, slightly increased [5]. The differences in the incidence between age groups in NH-I can be explained by the different occurrence of falls. TBIs in children under the age of 10 and adolescents are reported to be mostly non-intentional due to falling or slipping while playing [10,11]. Meanwhile, TBIs in children due to falls do not require hospitalization as they are mild in most cases [12,13]. Among people aged 70 years or older, TBI is a result of falling, as suggested by the higher incidence rate [14,15]. In other words, TBIs are mostly due to falls for those under the age of 10 and the elderly, and therefore, policy should be made to prevent TBIs for the child and elderly. Meanwhile, safety education and the use of safety helmets during leisure and sports activities are necessary for infants and children. In AUTO-I, the incidence of TBI in the 20–29, 30–39, 40–49, and 50–59 age groups was higher than that in the 0–9 and 70 or over age groups. TBIs due to RTAs are more prominent in the younger population [7]. Particularly, the low incidence of TBI due to car accidents in those under the age of 10 and in teens may be related to the acquisition of driver's license, as in the case of Korea where one must be 19 or older to obtain a driver's license, which could explain the low incidence rate of TBI in those aged 20 years and younger [16]. It could also be the result of the efforts of the Ministry of Land, Infrastructure, and Transport of Korea that has implemented policies to ensure the safety of children, the elderly, and the disabled, who are categorized as vulnerable populations [17]. On the other hand, TBIs related to low RTAs in those aged 70 years or older have been previously reported. In general, reports on falls as the cause of TBIs in the elderly population are increasing, while reports on TBIs due to RTAs are decreasing [18]. We also posited that the decrease in driving population in the elderly due to reduced physical and mental functioning from aging could be another cause. However, considering the aging population, the incidence of TBI due to traffic accidents is likely to increase. In fact, the incidence of traffic accidents in elderly drivers is increasing along with the aging population in Korea (2.9% in 2005, 8.2% in 2013) [19].

According to our results, there was an increase in total medical costs and costs of inpatient service per capita per year (medicine and oriental medicine) in both NH-I and AUTO-I. Particularly, in NH-I, the total cost of medical care and cost per capita per year in 2017 sharply increased compared to those in other years. In 2017, the Korean government implemented a policy to strengthen health insurance coverage called Moon Jae-in Care. One of the main contents of the policy to strengthen the coverage of health insurance is to convert non-reimbursable services, which increase the burden of medical expenses on patients, into NH-I. The increase in total and per capita per year medical costs in NH-I in 2017 can be interpreted as the effect of the policy. In oriental medicine in AUTO-I, the total cost of inpatient and outpatient both increased continually.

In addition, the average LOS and number of clinic visits were also longer in AUTO-I than in NH-I. It can be considered as the difference in nature between NH-I and AUTO-I. The NH-I is a social welfare system that allows people to receive necessary services and share risks

by paying insurance premiums on a regular basis. This prevents excessive expense burdens due to medical costs incurred by illness or injury. On the other hand, in the AUTO-I, the insurer (insurance company) of the person who causes the accident is responsible for the compensation to help the injured recover their physical and mental function [20], and the total medical costs are covered. Due to these characteristics, AUTO-I has excessive medical usage even for mild injuries, which is associated with a high hospitalization rate and long-term hospitalization [21]. In terms of severity, patients with mild injuries increased from 1,520,115 (93.2%) injuries in 2015 to 1,663,497 (94.5%) injuries in 2018 in AUTO-I. Also, the hospitalization rate, LOS, and the outpatient visit days in the mild severity group increased from 2010 to 2015 (hospitalization rate: 4.1% to 15.6%, LOS: 0.1 days to 0.9 days, Outpatient visit days: 2.3 days to 4.9 days, respectively). According to these sources, the recent rise in medical costs for minor injuries can be ascribed to the fact that medical expenses for RTA injuries are expected to be covered in full by AUTO-I. As a result, it is possible that medical services were used excessively or perhaps unnecessarily [22,23].

For oriental medicine, while costs of outpatient service per capita per year increased slightly from $447 in 2014 to $471 in 2017, the total medical costs increased sharply from $2.4 million in 2014 to $5.3 million in 2017. It may be due to wide coverages for oriental medicine in AUTO-I and the lack of knowledge in medical mechanism. The increase in the cost of oriental medicine may be as follows: 1) lack of clear medical fees and acceptable criteria; 2) absence of a specialized review body; 3) lack of information on the safety and efficacy of oriental medicine; and 4) blind spots for management and supervision due to many non-reimbursable items [24]. For example, herbal medicines provided by oriental medicine are prescribed indiscriminately to patients with automobile insurance without any special criteria for injury or disease. This is a factor that causes moral hazard in both medical providers and patients, and the use of oriental medicine for AUTO-I claims is emerging as a social issue. For these reasons, there will be a moral hazard because many mild patients use oriental medicine excessively.

Meanwhile, the medical costs for medical services and oriental medicine in AUTO-I data showed a large gap. However, this could be attributed to the timing of treatment following the patient's condition. For motor vehicle accidents, complex conditions, such as fractures, may be present in addition to TBI. In such cases, high-level and expensive medical services for fractures, for example, can be provided after hospitalization, and subsequent use of oriental medicine can be considered for the sub-acute phase or during the period requiring rehabilitation. In fact, the percentage of patients using combined medical services with oriental medicine has increased by 3.5%, from 17.9% in 2014 to 21.4% in 2015 [25]. The outpatient medical services in oriental medicine were concentrated at the clinic level and showed an annual increase of 24.6% [24].

To analyze the use of specialized rehabilitation therapy, patients who used the medical services for concussions (S06.0) alone were excluded, leaving only patients with moderate to severe injuries. The results of the analysis show that more prescriptions for specialized rehabilitation therapy were issued for patients with AUTO-I compared to those with NH-I (NH-I: 12.5 on average, AUTO-I: 35.4 on average). In addition, the number of specialized rehabilitation therapy prescribed to patients slightly decreased in NH-I (13.3 times in 2014, 11.8 times in 2017) and steadily increased in AUTO-I (30.3 times in 2014, 39.5 times in 2017). This is related to the severity of motor vehicle accidents. TBI patients from motor vehicle accidents are more likely to suffer from severe injuries than other TBI patients, with a higher likelihood of other complex injuries such as fractures [7,26,27].

This study is significant in that it utilized data from both NH-I and AUTO-I repositories to identify the overall incidence of TBI in Korea. However, the number of cases may have been underestimated in AUTO-I as the person who caused the accident might not receive treatment even in the case of RTAs. Meanwhile, due to data limitations, it is impossible to distinguish between the person who caused the accident and the injured in motor vehicle accidents, as well as between the driver, passenger, and pedestrians. As there are differences in the severity of injuries and treatment plans depending on the role at the time of motor vehicle accident, it is necessary to obtain and examine the information from the time of the accident in the future. Also, data for non-reimbursable services were unavailable from both the NH-I and AUTO-I in this study. The coverage rate of NH-I was 64.2% as of 2019, thus, approximately 35.8% was out-of-pocket expenses, which could include non-reimbursable expenses [28]. As a result, this study has a limitation in that it was not possible to analyze the medical cost of patients who received extra treatment from a non-reimbursable service. Therefore, non-reimbursable services should be considered in future studies to estimate the total medical costs accurately.

In conclusion, our results show differences in the incidence of TBI and medical usage between NH-I and AUTO-I, which could be associated with the policy for strengthening health insurance coverage, automobile-related regulations to prevent accidents and injuries, as well as rapid changes in the demographic structure of the aging population in Korea.

REFERENCES

1. Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung YC, Punchak M, Agrawal A, Adeleye AO, Shrime MG, Rubiano AM, Rosenfeld JV, Park KB. Estimating the global incidence of traumatic brain injury. J Neurosurg 2018:1-18.
   PUBMED | CROSSREF

2. Centers for Disease Control and Prevention (CDC). CDC grand rounds: reducing severe traumatic brain injury in the United States. MMWR Morb Mortal Wkly Rep 2013;62:549-552.
   PUBMED

3. Coronado VG, McGuire LC, Sarmiento K, Bell J, Lionbarger MR, Jones CD, Geller AI, Khoury N, Xu L. Trends in traumatic brain injury in the U.S. and the public health response: 1995–2009. J Safety Res 2012;43:299-307.
   PUBMED | CROSSREF

4. Majdan M, Plancikova D, Brazinova A, Rusnak M, Nieboer D, Feigin V, Maas A. Epidemiology of traumatic brain injuries in Europe: a cross-sectional analysis. Lancet Public Health 2016;1:e76-e83.
   PUBMED | CROSSREF

5. Kim HK, Leigh JH, Lee YS, Choi Y, Kim Y, Kim JE, Cho WS, Seo HG, Oh BM. Decreasing incidence and mortality in traumatic brain injury in Korea, 2008–2017: a population-based longitudinal study. Int J Environ Res Public Health 2020;17:6197.
   PUBMED | CROSSREF

6. Brazinova A, Rehorcikova V, Taylor MS, Buckova V, Majdan M, Psota M, Peeters W, Feigin V, Theadom A, Holkovic L, Synnot A. Epidemiology of traumatic brain injury in Europe: a living systematic review. J Neurotrauma 2021;38:1411-1440.
   PUBMED | CROSSREF

7. Peeters W, van den Brande R, Polinder S, Brazinova A, Steyerberg EW, Lingsma HF, Maas AI. Epidemiology of traumatic brain injury in Europe. Acta Neurochir (Wien) 2015;157:1683-1696.
   PUBMED | CROSSREF

8. Cassidy JD, Carroll LJ, Peloso PM, Borg J, von Holst H, Holm L, Kraus J, Coronado VGWHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 2004:28-60.
   PUBMED | CROSSREF

9. KOICD. Introduction of Korean standard classification of diseases. Available at https://koicd.kr/kcd/kcds.do [accessed on 8 June 2021].

10. Dahl E, von Wendt L, Emanuelson I. A prospective, population-based, follow-up study of mild traumatic brain injury in children. Injury 2006;37:402-409.
   PUBMED | CROSSREF

11. Haarbauer-Krupa J, Haileyesus T, Gilchrist J, Mack KA, Law CS, Joseph A. Fall-related traumatic brain injury in children ages 0–4 years. J Safety Res 2019;70:127-133.
   PUBMED | CROSSREF

12. Bazarian JJ, McClung J, Shah MN, Cheng YT, Flesher W, Kraus J. Mild traumatic brain injury in the United States, 1998–2000. Brain Inj 2005;19:85-91.
   PUBMED | CROSSREF

13. Keenan HT, Bratton SL. Epidemiology and outcomes of pediatric traumatic brain injury. Dev Neurosci 2006;28:256-263.
   PUBMED | CROSSREF

14. Kannus P, Niemi S, Parkkari J, Mattila V, Sievänen H. Fall-induced hospital-treated traumatic brain injuries among elderly Finns in 1970–2017. Arch Gerontol Geriatr 2020;86:103958.
   PUBMED | CROSSREF

15. Korhonen N, Niemi S, Parkkari J, Sievänen H, Kannus P. Incidence of fall-related traumatic brain injuries among older Finnish adults between 1970 and 2011. JAMA 2013;309:1891-1892.
   PUBMED | CROSSREF

16. Korean National Police Agency. The traffic laws. Article 82 (reasons for disqualification of driver's license). Seoul: Korean National Police Agency; 2021.

17. Ministry of Land, Transport and Maritime Affairs. National transportation safety plan 7th. Available at http://www.molit.go.kr/USR/BORD0201/m_69/DTL.jsp?mode=view&idx=155864 [accessed on 28 May 2021].

18. Stranjalis G, Komaitis S, Kalyvas AV, Drosos E, Stavrinou LC, Koutsarnakis C, Kalamatianos T. Recent trends (2010–2018) in traumatic brain injury in Greece: Results on 2042 patients. Injury 2020;51:2033-2039.
   PUBMED | CROSSREF

19. Lee WY, Kim KH, Oh JS. A study on the major factor of high-risk driver groups' accidents: focusing on elderly drivers. Wonju: Korea Road Traffic Authority; 2015.

20. Ministry of Land, Infrastructure and Transport. Guarantee of automobile accident compensation act, article 3 (liability for compensation for motor vehicle damage). Sejong: Ministry of Land, Infrastructure and Transport; 2021.

21. Kim J. Integrating insurance review systems and improving payment system of public health insurance. Available at http://repository.hira.or.kr/bitstream/2019.oak/995/2/%EC%A7%84%EB%A3%8C%EB%B9%84%20%EC%8B%AC%EC%82%AC%20%EC%9D%BC%EC%9B%90%ED%99%94%EC%99%80%20%EA%B3%B5%EB%B3%B4%ED%97%98%20%EC%88%98%EA%B0%80%EC%B2%B4%EA%B3%84%20%EA%B0%9C%EC%84%A0.pdf [accessed on 27 May 2021].

22. Jeon Y, Yang S, Kim Y. Review on Korea auto insurance bodily injury liability focusing on minor injury. Available at https://www.kiri.or.kr/report/downloadFile.do?docId=6101 [accessed on 28 May 2021].

23. Jeon Y. Current status of estimation of future medical expenditure for automobile insurance and improvement directions. Available at https://www.kiri.or.kr/publication/list.do?docId=2274&catId=28&parentCatId=0&searchCon=AUTHOR_NAME&searchWord=%EC%A0%84%EC%9A%A9%EC%8B%9D&page=1 [accessed on 3 June 2021].

24. Song YA, Li S. The present status and future direction of oriental medical services in the automobile insurance. Available at http://www.papersearch.net/thesis/article.asp?key=3642135 [accessed on 4 June 2021].

25. Lee C, Lee HJ, Chae J. A study on the analysis of factors for the increase of oriental medicine expenditure in the automobile insurance. J Korea Acad Ind Coop Soc 2019;20:121-130.

26. Kim JS, Jeong SW, Ahn HJ, Hwang HJ, Kyoung KH, Kwon SC, Kim MS. Effects of trauma center establishment on the clinical characteristics and outcomes of patients with traumatic brain injury: a retrospective analysis from a single trauma center in Korea. J Korean Neurosurg Soc 2019;62:232-242.
   PUBMED | CROSSREF

27. Tunthanathip T, Phuenpathom N. Impact of road traffic injury to pediatric traumatic brain injury in Southern Thailand. J Neurosci Rural Pract 2017;8:601-608.
   PUBMED | CROSSREF

28. National Health Insurance Service. Survey on the benefit coverage range of national health insurance. Available at https://www.nhis.or.kr/nhis/together/wbhaec08200m01.do?mode=view&articleNo=10803698&article.offset=0&articleLimit=10 [accessed on 11 October 2021].