

Clinical Article

Epidemiologic Impact of Rapid Industrialization on Head Injury Based on Traffic Accident Statistics in Korea

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Objective : The aim of the present study is to estimate the incidence trend of head injury and the mortality based on traffic accident statistics and to investigate the impacts of rapid industrialization and economic growth on epidemiology of head injury in Korea over the period 1970–2012 including both pre-industrialized and post-industrialized stages.

Methods : We collected data of head injury estimated from traffic accident statistics and seven hospital based reports to see incidence trends between 1970 and 2012. We also investigated the population structure and Gross National Income (GNI) per capita of Korea over the same period. The age specific data were investigated from 1992 to 2012.

Results : The incidence of head injury gradually rose in the 1970s and the 1980s but stabilized until the 1990s with transient rise and then started to decline slowly in the 2000s. The mortality grew until 1991 but gradually declined ever since. However, the old age groups showed rather slight increase in both rates. The degree of decrease in the mortality has been more rapid than the incidence on head injury.

Conclusion : In Korea during the low income stage, rapid industrialization cause considerable increase in the mortality and the incidence of head injury. During the high income stage, the incidence of head injury gradually declined and the mortality dropped more rapidly than the incidence due to preventive measures and satisfactory medical care. Nevertheless, the old age groups revealed rather slight increase in both rates owing to the large population structure and the declining birth rate.

Key Words : Epidemiology · Head injury · Industrialization.

INTRODUCTION

Traumatic injuries have a considerable impact on the population's health in terms of mortality, morbidity and disability^{1,21)}. Trauma is the major cause of death for all age groups in most countries as well as in Korea. Approximately half of all trauma deaths are associated with head injury, and more than 60% of traffic accidental deaths are due to head injury^{3,23)}. Some patients who survive the primary injury are frequently left with significant neurological deficit and often require prolonged hospitalization or long-term care. This situation would result in extended loss of productive function and a prohibitive cost for the country^{4,8)}.

As a general rule, it is difficult to discover reliable statistics from routinely collected data. Referring the several available

statistics, death rate from traumatic injuries does not identify head injuries, although their incidence reflects geographical differences and trends over time in the frequency of trauma deaths as a whole¹¹⁾. Epidemiologic study of head injury in Korea is very important because tremendous increase in the number of traffic accidents has been observed with its rapid industrial and economic growth. Korea had one of the world's fastest growing economies from the early 1970s to the late 1990s, and remains one of the fastest growing developed countries in the 2000s.

Statistics by national health insurance databank was available only from 2004. It wasn't until 2010 that the Korea Trauma Data Bank Committee was founded within Korean Society of Neurotrauma for epidemiologic study¹⁸⁾. Consequently the authors tried to outline the trend of incidence of head injury using Traffic Accident Statistical Database from 1970 to 2012 and seven

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reports of hospital based head injury. The aim of the present study is to estimate the incidence of head injury based on traffic accident statistics and to describe the incidence trends and the impacts of rapid industrialization on head injury epidemiology in Korea over the period 1970–2012 including both of developing and developed terms.

MATERIALS AND METHODS

It is of limited value that reports of head injuries are carried out by clinicians. Because the several different specialists are responsible for head injuries of different severities with varying admission and transfer policies, it is not easy to put these reports into an epidemiological setting. Furthermore, most head injuries admitted to hospital are mild, but many clinical reports are produced by neurosurgeons who focus only on the 5–10% of severe or complicated injuries that are transferred to them. Therefore it is very demanding to acquire the total number of head injuries in Korea.

Our concern is not to know the total number of head injuries but to understand the trend of epidemiology on head injury before and after industrialization. Statistics by national health insurance databank was available only from 2004. It wasn't until 2010 that the Korea Trauma Data Bank Committee was founded within Korean Society of Neurotrauma for the purpose of injury prevention, clinical research and policy development on head injury. Consequently the authors tried to outline the trend of incidence of head injury and to understand epidemiologic effects of rapid industrialization on head injury using Traffic Accident Statistical Database from 1970 to 2012 and seven reports of hospital based head injury. There are two different types of databases on traffic accident statistics. The first is the Police Road Accident Database and the second is the Integrated Road Accident database, the latter being an aggregated database from police, insurance companies and mutual aid associations. The latter is more reasonable and realistic but has data only from 2007 not including developing stage. Thus we used the first data to cover both before and after industrialization.

Lee¹⁶⁾ estimated the incidence of head injury by reviewing seven hospital based reports (Table 1) and applying to national traffic accident statistics. Analyzing the cause of head injury on those reports by hospitals, the traffic accident was about 62.5% of all head injuries. He made approximate calculations of the incidence of head injury by a formula $H=T/0.625$ (H : the total number of head injury, T : the total number of patients due to

traffic accidents). In the same way we estimated the incidence of head injury from 1970 to 2012 and plotted a line graph for easy interpretation of the trend of the incidence and the mortality on head injury. The age specific data on traffic accidents are unfortunately available from 1992. They were displayed on a line graph with separate 8 age-groups.

We also investigated Gross National Income (GNI) per capita quoting the data reported by World Macroeconomic Research¹⁰⁾ and the population pyramid produced by Statistics Korea over the same period. And we tried to investigate how the structure of population and the growth of GNI by industrialization make an impact on epidemiology of head injury.

RESULTS

Referring to the result of Traffic Accident Statistical Database by The Korea Road Traffic Authority, the number of head injury patients due to motor vehicle accidents was 42830 in 1970, 111641 in 1980, 324229 in 1990, 426984 in 2000, and 344565 in 2012 (<https://taas.koroad.or.kr/>). Consequently using the above estimation formula performed by Lee, the total number of patients with head injury would be 68528 in 1970, 178625 in 1980, 518766 in 1990, 683174 in 2000 and 551304 in 2012. According to the material produced by Statistics Korea, the population of Korea was 32240827 in 1970, 38123775 in 1980, 43295704 in 1991, 47008111 in 2000, and 50004441 in 2012 (<http://www.kostat.go.kr/>). Accordingly the annual incidence rate of head injury per 100000 would be 130.2 in 1970, 315.2 in 1980, 614.3 in 1991, 517.9 in 1998, and 467.1 in 2012. We plotted all the calculated data of annual incidence on head injury in the linear

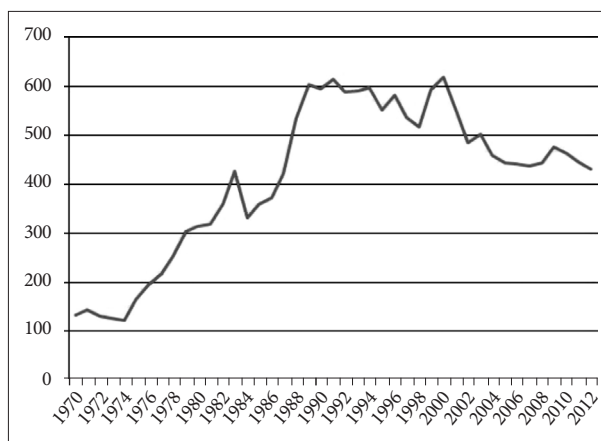


Fig. 1. Trends of estimated incidence on head injury per 100000 population.

Table 1. Hospital reports on the head injury in Korea

	Cho et al. ⁶⁾	Rhee et al. ²²⁾	Moon et al. ¹⁹⁾	Lee et al. ¹⁷⁾	Jun et al. ¹²⁾	Lee et al. ¹⁵⁾	Kim et al. ¹⁴⁾
Traffic accident, %	50.90	57.30	76.60	62.20	58.10	55.20	77.10
Fall, %	31.80	25.50	11.60	9.00	5.90	18.70	6.90
Others, %	17.40	17.30	11.90	28.80	36.00	17.30	16.00
Study period, year	1966–1971	1966–1971	1971–1977	1972–1976	1980–1984	1982–1983	1986–1987
Total no. of patients	340	585	1523	1547	1210	667	1000

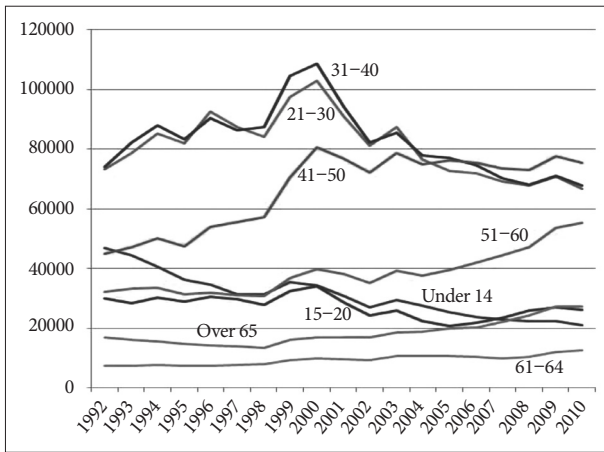


Fig. 2. Age specific trends by the number of injured person on traffic accidents.

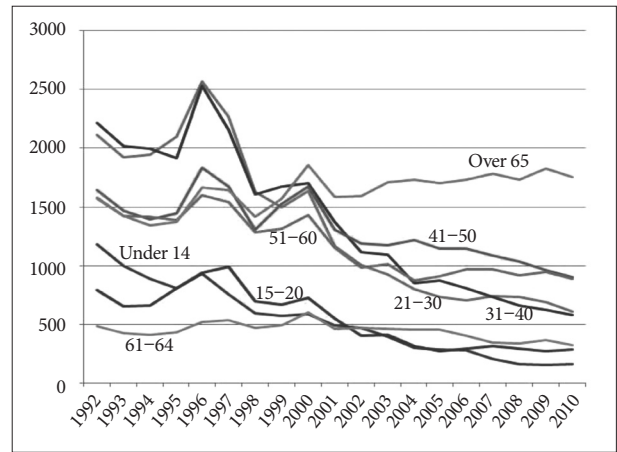


Fig. 4. Age specific trends of the number of death on traffic accidents.

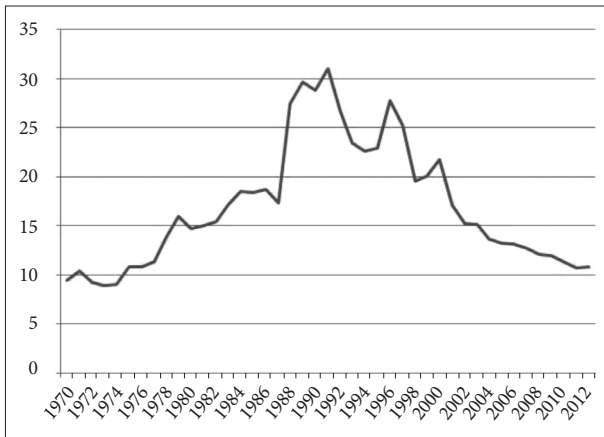


Fig. 3. Trends of the mortality on traffic accidents per 100000 population.

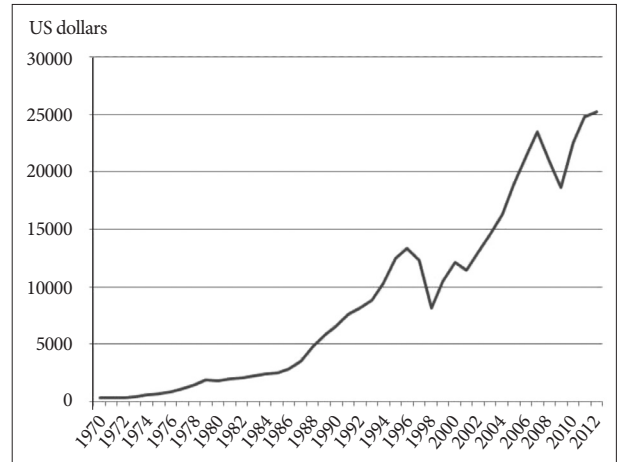


Fig. 5. Gross National Income per capita reported by World Macroeconomic Research¹⁰⁾.

graph from 1970 through 2012 to estimate the trend of the incidence of head injury (Fig. 1). The incidence trend displayed steady increase in the 1970s and the 1980s. It was stabilized in 1990s with some fluctuations and then started to decline in 2000s. The age specific data on traffic accidents revealed different appearance by age groups. The age group of 20s and 30s represented highest incidence, which reached a peak in 2000 and then declined gradually. On the contrary, the incidence trends of the old age groups over 50 increased slightly (Fig. 2).

As a result of traffic accident, according to the Traffic Accident Statistics the total number of death was 3051 in 1970, 5608 in 1980, 13429 in 1991, 10236 in 2000 and 5392 in 2012. Taking into account of the total population of Korea in each year, the annual mortality rate per 100000 would be 9.5 in 1970, 14.7 in 1980, 31.0 in 1991, 21.8 in 2000, and 10.8 in 2012. We draw all the data of annual mortality on traffic accidents in the linear graph from 1970 through 2012 to understand the trend of the mortality (Fig. 3). The mortality trend per 100000 population showed gradual increase until 1991. And after that time it has been declining with some changes. Between 1990 and 2012, the number of road fatalities decreased by 62%, while the number

of the injured decreased by only 12.4%. Although there was transient increase in around 1996, as a whole age specific mortality trends declined gradually with some fluctuation except the age group over 65. On the contrary it was slightly increasing in the age group over 65 (Fig. 4).

World macroeconomic research announced GNI per capita in Korea was 302 dollars in 1970, 1777 dollars in 1980, 5509 dollars in 1990, 12127 dollars in 2000, and 25120 dollars in 2012 (<http://www.kushnirs.org/macroeconomics/>). During 1970–2013 GNI per capita in Korea grew exponentially by 26416 dollars (in 88.4 times) to 26718 dollars (Fig. 5). The average annual growth of GNI per capita in Korea was 614.3 dollars or 203.2%.

DISCUSSION

Data on the incidence figures for head injury was lacking in Korea excluding some hospital based reports. Statistics by national health insurance databank did not provide information on low income and pre-industrial stage. The Korea Trauma Data Bank started to work on programs only from 2010. Therefore the authors had no choice but to use Traffic Accident Sta-

tistical Database from 1970 to 2012 to outline the trend of incidence of head injury and tried to understand epidemiologic impacts of rapid industrialization on head injury.

The reported annual incidence of head injury has varied widely owing to different study methods, case definitions, time periods and geographic locations although many studies are based primarily or exclusively on hospitalized cases and mortality³⁾. Differences in study methods of head injury may result in divergent estimates of numbers and make inter-study comparison difficult. However when inclusion and exclusion criteria are considered, the relative incidences and trends are congruent.

Since the Korea Trauma Data Bank System has problems to perform our epidemiological purpose¹³⁾, we employed Lee¹⁶⁾'s estimation in this article that the traffic accident was about 62.5% of all head injuries based on reviewing seven hospital based reports^{6,11,13,14,16,18,20)}. This estimation has a minor problem that those hospital reports were performed in the short term and early stage between 1966 and 1987. However this would not be trouble as the aim of this study was to assess the trend of incidence rather than actual incidence for head injury over the period 1970–2012.

During the 1970s and the 1980s the incidence trend of head injury revealed constant increase. At that time civic consciousness of keeping the road traffic law was lacking. According to World Macroeconomic Research, GNI per capita in Korea was 302 dollars in 1970, 649 dollars in 1975, and 1777 dollars in 1980. Thus we were at low income stage in 1970s. However we started to accelerate industrialization in 1980s to break out of low income stage. As a result of rapid industrialization GNI per capita had increased to 2495 dollars in 1985, 4766 dollars in 1988 (the year of Seoul Olympic), and 6,608 dollars in 1990. Especially Korea has observed a very rapid increase in motorization due to the development of automobile manufacturing industry in 1980s and 1990s. In spite of more rapid increase of in the number of motor vehicles, the incidence of head injury was stabilized in 1990s with some fluctuations and then continued to decline in 2000s. The mortality trend per 100000 population showed gradual increase until 1991, which peaked in 1991 at 13429. Since then, road deaths have decreased with some fluctuations and were halved in 2004. This important decrease is due in part to the several measures of reinforcement on road traffic laws, which include the compulsory wearing of front seatbelts in 1990, nation-wide implementation of speed enforcement cameras since 1997 and enforcement against drunk driving in 1998. In Taiwan and United States, the number of motorcycle-related injuries declined considerably by 33% after the implementation of the motorcycle helmet law²⁵⁾. Becoming high-income people, civic consciousness on traffic safety was much improved. Between 1990 and 2012, the rate of decrease for the mortality has been more rapid than the incidence of head injury. This means that the severity of accidents has diminished more rapidly than their occurrence owing to Strengthening Safety Policy²⁵⁾. In addition, Korea made great and rapid strides

in the health care delivery system especially on head injury. Various diagnostic and treatment modalities have been introduced to improve the outcome of head injury. Neurosurgical intensive care unit (NICU) was set up on a nation-wide scale to manage severe traumatic brain injury In 1960s, 1970s. At present, monitoring of ICP, brain oxygen, and cerebral blood flow is available for better outcome at NICU. In terms of treatment modalities, induced hypothermia, barbiturate coma therapy, and hyperosmotic therapy can be beneficial for severe traumatic brain injury.

Both of age-associated incidence and mortality trends display peak in 21–40 age groups because they are most energetic during life. Contrary to young age, both of incidence and mortality trends of old age show slightly increasing tendency in spite of high income stage and satisfactory quality of medical care. Age is an important factor influencing outcome after severe head injury. In general, the older the victim is, the higher the probability of a poor outcome is^{9,24)}. Older patients have been reported to have a markedly higher complication and death rates, which might be involved in the age-dependent mortality in trauma victims^{7,20)}. In addition, seeing the incidence and mortality rate was increasing in old age, it was necessary to understand 4-stage population pyramids of demographic transition model in Korea (Fig. 6). Demographic transition refers to the transition from high birth and death rates to low birth and death rates as a country develops from a pre-industrial to an industrialized economic system. Population pyramid of 1960 in Korea come under stage one, pre-industrial society, death rates and birth rates are high and roughly in balance. Population pyramid of 1980 is equivalent to stage two, that of a developing country, the death rates drop rapidly due to improvements in food supply and sanitation. Population pyramid of 1995 falls under stage three, birth rates decrease due to access to contraception, increases in wages, urbanization, a reduction in subsistence agriculture. Population pyramid of 2010 is applicable to stage four. There are both low birth rates and low death rates. After all, Korea has the large aging population and the declining birth rate. This would be the one of major reasons why incidence and mortality rate of the old age was continuously increasing.

With respect to incidence of head injury in this study, popu-

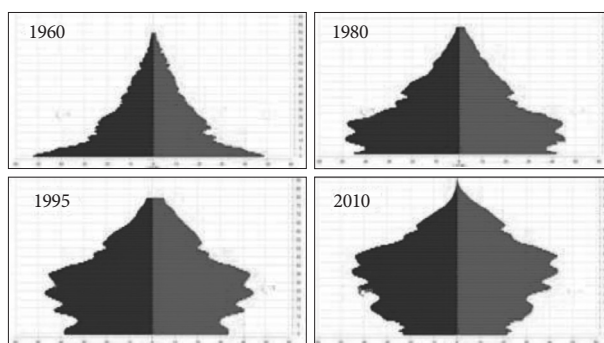


Fig. 6. Four-stage population pyramids of demographic transition model in Korea referring to data produced by Statics Korea.

lation of ages from 51 to 60 shows most dramatic increase in incidence, whereas the fatality is highest in population of ages more than 65. On this peculiar finding we need to consider preexisting disease. Although we could not investigate about preexisting disease with head injury in old patients in this study, according to report from the Japan Neurotrauma Data Bank, the older group had a significantly higher rate of preexisting disease²⁴. Furthermore, alteration in the pathophysiological response, which is related to the development of secondary brain injury in the aging brain, probably contributes to more severe and irreversible brain damage in older patients, and is thus associated with poor outcomes²⁴.

Epidemiological studies on head injury are required to initiate appropriate preventive measures and to plan necessary services. However, in Korea there has been few nationwide epidemiologic survey on head injury. At long last, the Korea Trauma Data Bank Committee for Head Injury began its formal activity in 2010. However, since it has still lots of incomplete or incomprehensible data and less specified items for cause of injury, we need to make much more improvements to neuro-trauma data bank for more nation-wide project on epidemiology of head injury^{13,18}.

CONCLUSION

Although at the moment epidemiologic study of head injury is an under-researched in Korea, investigating the traffic accident statistic data analysis and reviewing some medical reports, the results of this study support the following fact. In Korea during the low income and pre-industrial stage, rapid industrialization especially on very rapid motorization cause considerable increase in mortality and incidence of head injury. During the high income and post-industrialized stage, despite rapid increase in the number of motor vehicles the incidence of head injury gradually declined and the mortality dropped more rapidly than injuries. However, in spite of preventive measures of traffic accidents and satisfactory quality of medical care, the old age groups revealed rather slight increase in both of the mortality and incidence of head injury owing to the large aging population and the declining birth rate shown by population pyramid.

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References

- Andersson EH, Björklund R, Emanuelson I, Stålhammar D : Epidemiology of traumatic brain injury : a population based study in western Sweden. *Acta Neurol Scand* 107 : 256-259, 2003
- Bachulis BL, Sangster W, Gorrell GW, Long WB : Patterns of injury in helmeted and nonhelmeted motorcyclists. *Am J Surg* 155 : 708-711, 1988
- Bruns J Jr, Hauser WA : The epidemiology of traumatic brain injury : a review. *Epilepsia* 44 Suppl 10 : 2-10, 2003
- Chiu WT, Hung CC, Shih CJ : Epidemiology of head injury in rural Taiwan - a four year survey. *J Clin Neurosci* 2 : 210-215, 1995
- Chiu WT, Kuo CY, Hung CC, Chen M : The effect of the Taiwan motorcycle helmet use law on head injuries. *Am J Public Health* 90 : 793-796, 2000
- Cho MK, Rhee HJ, Kim Y, Choi KS, Chu JW, Sim BS : A clinical observation on craniocerebral injuries in infants and Children. *J Korean Neurosurg Soc* 1 : 79-86, 1972
- Finelli FC, Jonsson J, Champion HR, Morelli S, Fouty WJ : A case control study for major trauma in geriatric patients. *J Trauma* 29 : 541-548, 1989
- Frankowski RF : Descriptive epidemiologic studies of head injury in the United States : 1974-1984. *Adv Psychosom Med* 16 : 153-172, 1986
- Hernesniemi J : Outcome following head injuries in the aged. *Acta Neurochir (Wien)* 49 : 67-79, 1979
- Ivan K : E-book. Macroeconomics in Korea. World macroeconomic research, 1970-2013
- Jennett B, MacMillan R : Epidemiology of head injury. *Br Med J (Clin Res Ed)* 282 : 101-104, 1981
- Jun YH, Kim TS, Kim KM, Kim GK, Rhee BA, Leem W : A clinical analysis and assessment of outcome by glasgow coma scale in 1210 adult head injury. *J Korean Neurosurg Soc* 15 : 395-418, 1986
- Kim DH : Historical review of Japan Neurotrauma Data Bank (JNTDB). *Korean J Neurotrauma* 9 : 31-35, 2013
- Kim WH, Lee KS, Bae HG, Yun IG, Lee IS : A clinical analysis on 1000 consecutive head injuries. *J Korean Neurosurg Soc* 18 : 290-300, 1989
- Lee BW, Han YP, Chung SS, Lee KC : Clinical features of craniocerebral injury in children. *J Korean Neurosurg Soc* 14 : 153-168, 1985
- Lee KS : Estimation of the incidence of head injury in Korea : an approximation based on national traffic accident statistics. *J Korean Med Sci* 16 : 342-346, 2001
- Lee SC, Choi SK, Lee YS, Lyu SY, Jang KY, Hwang DY, et al. : A clinical observation on craniocerebral injuries in adults : analysis of 1547 cases. *J Korean Neurosurg Soc* 6 : 435-452, 1977
- Lee SK; Korean Trauma Data Bank Committee : Understandings and key elements of trauma data bank system. *Korean J Neurotrauma* 8 : 1-9, 2012
- Moon SB, Kang YC, Kim YC, Kim SJ, Kim GK, Rhee BA, et al. : Clinical analysis of associated injuries in head injured patients. *J Korean Neurosurg Soc* 6 : 379-390, 1977
- Pennings JL, Bachulis BL, Simons CT, Slazinski T : Survival after severe brain injury in the aged. *Arch Surg* 128 : 787-793; discussion 793-794, 1993
- Pérez K, Novoa AM, Santamariña-Rubio E, Narvaez Y, Arrufat V, Borrell C, et al. : Incidence trends of traumatic spinal cord injury and traumatic brain injury in Spain, 2000-2009. *Accid Anal Prev* 46 : 37-44, 2012
- Rhee HJ, Choi MK, Kim Y, Choi KS, Chu JW, Sim BS : A clinical observation on craniocerebral injuries in adult. *J Korean Neurosurg Soc* 1 : 67-78, 1972
- Sosin DM, Sniezek JE, Waxweiler RJ : Trends in death associated with traumatic brain injury, 1979 through 1992. Success and failure. *JAMA* 273 : 1778-1780, 1995
- Tokutomi T, Miyagi T, Ogawa T, Ono J, Kawamata T, Sakamoto T, et al. : Age-associated increases in poor outcomes after traumatic brain injury : a report from the Japan Neurotrauma Data Bank. *J Neurotrauma* 25 : 1407-1414, 2008
- Yang BM, Kim J : Road traffic accidents and policy interventions in Korea. *Inj Control Saf Promot* 10 : 89-94, 2003